Materials & Methods

THE MAGAZINE OF MATERIALS ENGINEERING ®

VOLUME 29, NUMBER 3 • MARCH, 1949

FEATURE ARTICLES

MATERIALS & METHODS MANUAL NO. 47

ENGINEERING FILE FACTS

DEPARTMENTS

NEXT MONTH Liquid Impact Blast Cleaning . . . Automatic Flame Hardening . . . Magnesium Die Castings . . . Redesigning for Electric Furnace Brazing . . . New Structural Insulator . . . Forging High Temperature Alloys . . . Rust as an Insulator for Magnetic Laminations . . . GRAY IRON CASTINGS (Materials & Methods Manual No. 48)

...lished monthly by Reinhold Publishing ...poration, 330 West 42nd St., New York ... N. Y., U. S. A. Ralph Reinhold, Chair... of the Board; Philip H. Hubbard, Pres...nt; H. Burton Lowe, Executive Vice Pres...t; G. E. Cochran, Vice President and ...retary; W. P. Winsor, Vice President; ...P. Peters, Vice President; J. G. Belcher, ... President; W. F. Traendly, Vice Presi..., Francis M. Turner, Vice President. ...e 50 cents a copy. Payable in advance, ... year, $2.00; two years, $3.00; three ...s, $4.00; five years, $5.00 in U. S. ... Possessions, Canada and Pan American ...on. $2.00 extra for each year in all ...er countries. (Remit by New York Draft.)

Reentered as second class ...tter Nov. 14, 1945, at the Post Office at ...ew York, N. Y. under Act of March 3, 1879. ...ablished in 1929 as Metals and Alloys.

Fifth Annual Meeting and Exhibition

Metal Powder Association

April 5 and 6, 1949
Chicago, Ill.

The fifth annual meeting of the Metal Powder Association is to be held April 5 and 6 at the Drake Hotel in Chicago, Ill. In conjunction with the technical sessions, an exhibit is planned with approximately 20 companies taking space. Last year's attendance of over 200 persons is expected to be exceeded.

Papers on technical and sales problems will be presented on Tuesday afternoon and Wednesday morning. Seven papers have been scheduled to be given during the two sessions.

Activities will start at 10:30 a.m. Tuesday, April 5, with an informal round table session during which problems of the day will be discussed.

Social activities of the two-day meeting will be limited to a cocktail party at 5:30 p.m. Tuesday and a luncheon at 12:30 p.m. Wednesday.

THE PROGRAM

Tuesday, April 5

10:30 a.m.—Informal Round Table
2:15 p.m.—"Tolerances of Finished Powder Metal Parts"—W. R. Toeplitz, vice president, Bound Brook Oil-Less Bearing Co.
3:00 p.m.—"Some Effects of Oxygen on the Performance of Iron Powder"—J. J. Cordiano, sales manager, Buel Metals Co.
3:45 p.m.—"Hygiene in the Metal Powder Industry"—Dr. Johns, medical consultant
4:30 p.m.—"Selling Parts Made from Metal Powders"—Morris Boorky, president, The Presmet Corp.
5:30 p.m.—Cocktail Party

Wednesday, April 6

10:00 a.m.—"Effect of Impurities in Metal Powders"—F. V. Lenel, Rensselaer Polytechnic Institute
10:45 a.m.—"Powder Metallurgy from the Design Engineer's Viewpoint"—J. L. Bonanno, engineering department, Lionel Corp.
11:30 a.m.—"Characteristics of Materials Involved in the Magnetic Fluid Clutch"—H. D. Saunderson, National Bureau of Standards
12:30 p.m.—Luncheon

EXHIBITORS

Company	Space
American Instrument Co., Silver Springs, Md.	10
American Metal Co., New York	13
Antara Products, New York	16
Electric Furnace Co., Salem, Ohio	3
Federal-Mogul Corp., Detroit	18
General Machine Co. of New Jersey, Newark	14
Chas. Hardy, Inc., New York	17
Kux Machine Co., Chicago	20
Metals Disintegrating Co., Elizabeth, N. J.	6
Metals Refining Co., Hammond, Ind.	19
National Bureau of Standards, Washington	11
New Jersey Zinc Co., New York	4
Plastic Metals Div., National Radiator Co., Johnstown, Pa.	1 & 2
Powdered Metal Products Corp. of America, Franklin Park, Ill.	15
F. J. Stokes Machine Co., Hammond, Ind.	9
Wel-Met Co., Kent, Ohio	5
S. K. Wellman Co., Cleveland	7

EDITORIAL

Powder Metallurgy and the Future

As is pointed out in the leading article of this issue, powder metallurgy as an industry is at the crossroads. It can either retreat into its shell and be a completely mysterious process, or it can move forward and take its place as a production method which competes on its merits with other methods. Some of the leading men in the powder metallurgy field recognize the situation, but too many are prone to hide their heads, ostrich-like, and avoid facing the facts.

Like other new processes, powder metallurgy has sometimes been oversold. Claims have been made for it that are not justified and promises have been made that could not be kept. Either approach is a quick method of losing friends and customers. Enthusiasm for a process is natural among its pioneers, but persons buying parts look at the matter with a more detached viewpoint. Clearer thinkers among producers of powder metal parts are now working to overcome bad impressions already created.

However serious the above situation may be, a worse common fault is the absence of an honest interchange of information. At this moment many of the leaders in powder metallurgy are the type of men who have worked out their own problems. Most guard their secrets like an alchemist who has learned the secret of producing gold. They fail to realize that any steps which can be taken to advance their industry as a whole is bound to help them as individual scientists or companies.

Recently this magazine published an article on which was described a helical gear produced of powder metals. Although our writer had conclusive evidence that such a gear was and is in production, several powder metal men said it is impossible. We would not suggest that a company which can do what others claim is impossible should reveal all its secrets. The mere fact that it proves it can do the so-called impossible should spur others on to doing similar work.

All is not dark in the picture, however, since a group now meets regularly to work together on the industry's common problems. The Metal Powder Association will hold its fifth annual meeting in Chicago early in April. Each successive meeting of the Association shows a greater liberalization of viewpoint and a further breaking down of the barriers which have held powder metallurgy back.

We hope the trend continues, for it would be a serious thing if progress in the use of powder metals were to be halted. Wartime uses of powder metal parts proved they can be good. Now let's prove they can be both good and economical.

T. C. Du Mond
Editor

Carbide tool tips have long been a standard powder metallurgy product. Here a length of sintered carbide is being cut into small nibs or tips. (Courtesy: The Hydraulic Press Manufacturing Co.)

The ability of powder metallurgy to provide low-cost parts with satisfactory properties depends on a number of problems now facing the industry.

Where Does Powder Metallurgy Stand Today?

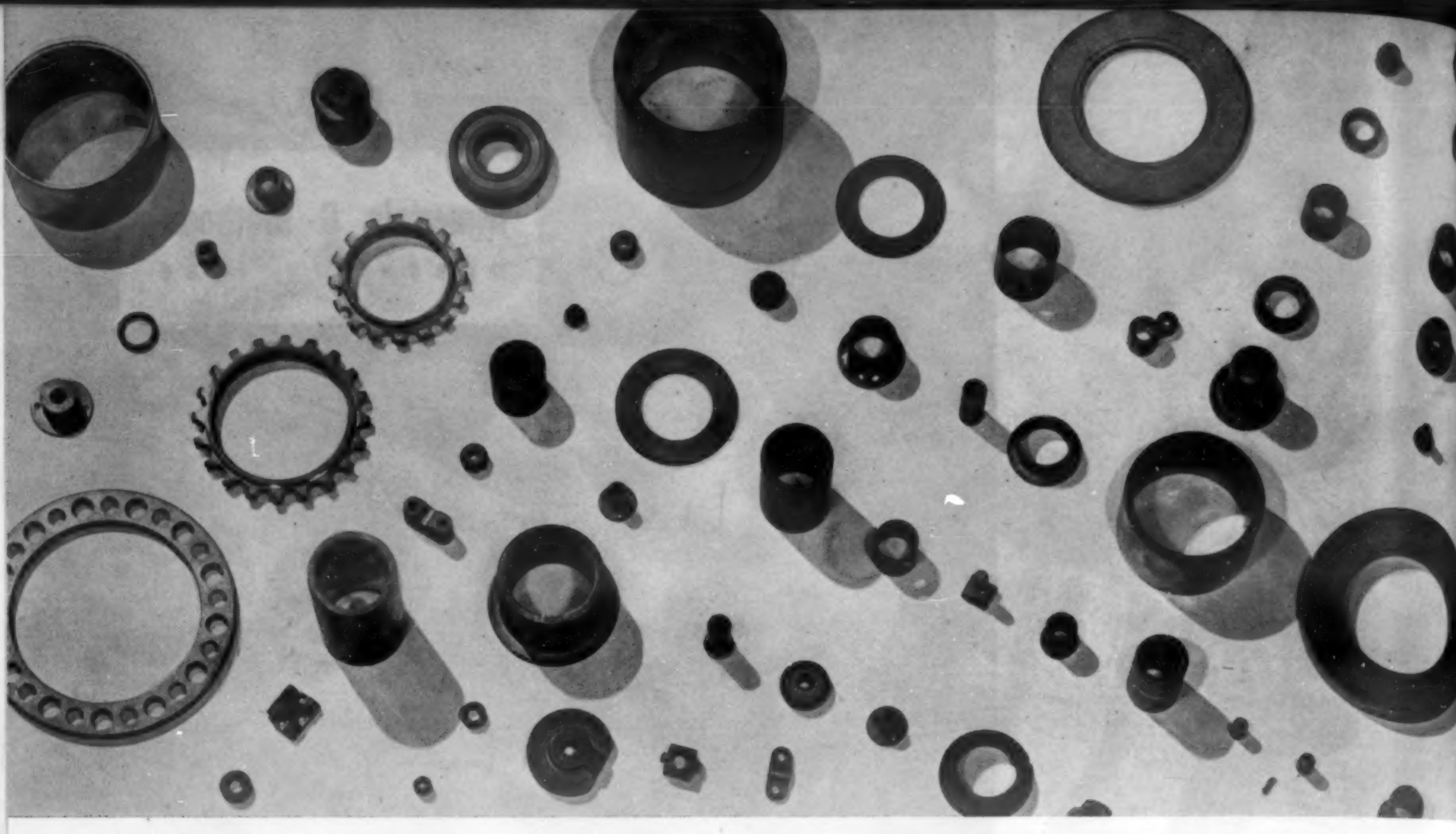
by H. R. CLAUSER, Associate Editor, Materials & Methods

• POWDER METALLURGY has now been available to industry on a reasonably large scale for about ten years. Yet industry is still somewhat confused as to just what the process can and cannot do and where it can best fit into the metal parts production picture. The main reason for this uncertainty is that from the engineering and practical standpoint powder metallurgy is still a relatively young process, and like other new technical developments that have been introduced with a landslide of publicity, it is having trouble settling down to a definite range of uses that are clearly defined by its real capabilities and limitations.

The problems that beset the powder metallurgy field in this settling-down-process are both technical and nontechnical, and this article will discuss what are believed to be some of the more important ones and thus try to show the prospective user and producer of metal powder parts what he can and cannot expect now and in the near future.

High-Quality, Low-Cost Powders?

The progress of powder metallurgy as a large scale production process is closely tied to advances made in metal powders, and to the availability of high quality metal powders at rea-



A typical assortment of bushings and other small parts made by powder metallurgy. (Courtesy: Keystone Carbon Co.)

sonably low cost. The past few years have seen improvements in both the processing characteristics and properties of metal powders, and development of a number of new powders with higher mechanical properties. But there has been no noticeable downward trend in the cost of metal powders.

The principal metal powders presently used in powder metallurgy are copper, bronze, brass and iron. Today there is no shortage of any of these. Of the principal powders, bronze is used in the greatest quantity, its chief application being for self-lubricating porous bearings. Brass and iron powders are the most widely used for mechanical parts. Although they are finding increased use in this field, their future depends largely on the development of new markets for powder metallurgy products in competition with the older conventional metal forming methods.

Of these two powders, brass is in a more favorable position costwise when the cost of brass powder (around 30c per lb.) is compared to that of brass wrought stock and of brass ingots. Brass powder is a few cents cheaper than wrought stock and only slightly higher in cost than brass in ingot form.

However, in the case of iron, the difference is much larger. The price of iron powders now ranges all the way from about 10c per lb. for low-grade iron to over a $1.00 per lb. for very high grades. Even the lowest grades of iron powders run 7 to 10c per lb. more than the raw materials for cast products, and several cents higher than wrought steel forms. For this reason the expansion of the use of iron powder is closely linked with the development of lower cost high quality powders.

In the past, much of our iron powder has been imported from Sweden and also some from Germany. Many fabricators are still using Swedish powder. In fact, until the past several years the Swedish process had been the only commercial method of making iron powder at relatively low cost. During the past few years, domestic production capacity of iron powders has been increased by the development and use of several new production methods so that our domestic capacity is now above 10,000 tons per year. But at present this capacity is not being fully used. And the cost of iron powders is closely connected with this capacity production. For it is generally believed that prices will not be considerably reduced until much larger capacity plants are built; but larger plants cannot be justified until the demand for the powders is greatly increased. Thus, the field faces the problem of creating a demand and finding new markets without the aid of low cost raw materials. In spite of high material costs, it must prove its worth on the basis of such merits as its high rate of production, low metal loss, and elimination of machining costs.

The relatively low mechanical properties, such as strength and ductility, compared to those obtainable in cast and wrought metals has always been and still is an important factor upon which the growth of the use of metal powder parts depends. Development of pre-alloyed powders has been an important step towards improving the properties of metal powder parts. In pre-alloyed powders two or more elements are present in the powder in alloyed form; thus, the alloying action does not depend upon diffusion during the sintering operation.

There are several advantages obtained with pre-alloyed powders. Blending and mixing operations are eliminated; the powders have more uniform processing characteristics and provide a more uniform product; the sintering time is reduced over that necessary for diffusion sintering; and perhaps most important, mechanical properties are improved.

How much the mechanical properties are improved depends to a large extent upon the compressibility of the powder. Test results on present day pre-alloyed steel powders indicate that densities are being achieved that bring some of the mechanical properties close to those of wrought products. For example, a 0.20% carbon pre-alloyed steel pressed at 40 tons and sintered in a dissociated ammonia atmosphere for 45 min. has the following properties: tensile strength

26,400 psi., 4% elongation, and a Rockwell hardness of 84H. By coining at 50 tons pressure the tensile strength is increased to about 51,000 psi., the elongation is 1% and hardness is Rockwell 41G. Thus, while relatively high strength and hardnesses can be obtained, elongation still remains a problem.

While pre-alloyed steels are available in the range from 0.20 to around 1.20% combined carbon, the higher carbon contents find only limited use, because high particle hardness considerably reduces their compressibility.

Brass powders have been pre-alloyed commercially for quite a number of years and their use for mechanical parts has been expanding. Considerable success has been reported for the process in which iron powder parts are impregnated with brass or lead during the sintering operation to increase density, strength and ductility.

Aluminum powder is also beginning to receive some attention for use in making small parts. A new aluminum powder is now on the market which is reported to have properties close to those of wrought pure aluminum in the annealed condition. In this powder the oxide film on the particles is removed by an etching agent which then serves as the lubricant during pressing.

Control of Variables

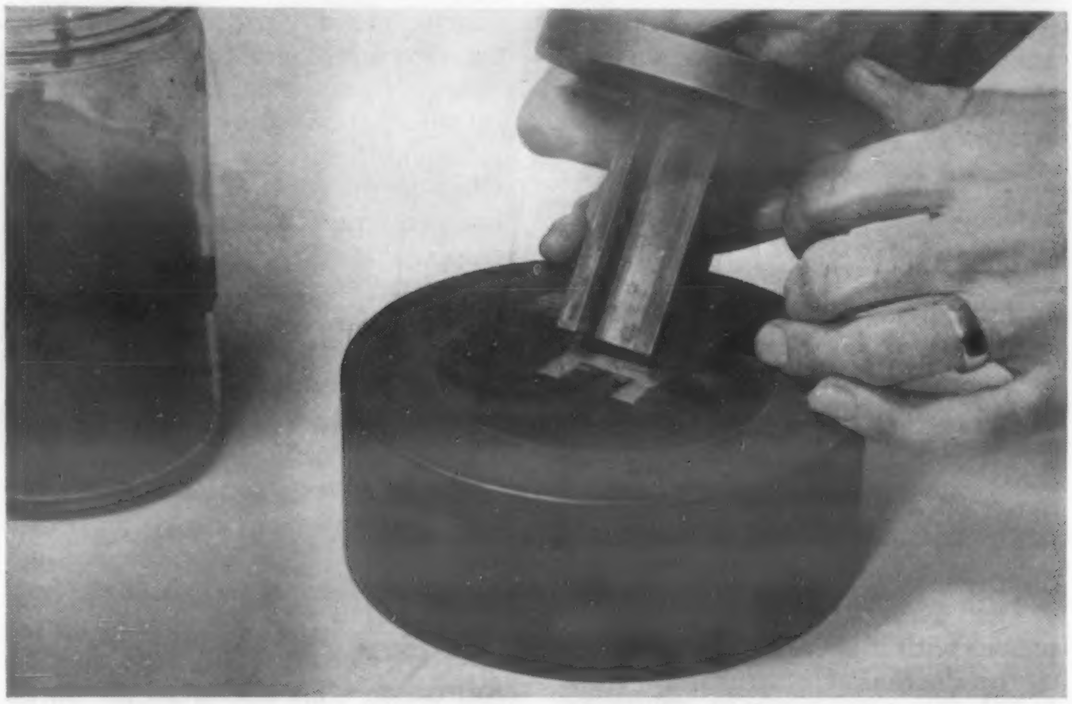
One of the leaders in the powder metallurgy field said recently that he has counted no less than 50 variables that had to be controlled in the production of a metal powder part. And he felt sure that he had missed some. His count includes variables in the metal powder itself as well as those encountered during pressing and sintering. In the sintering operation alone a few of the many variables are maximum temperature, rate of heating and cooling, time at temperature, analysis of atmosphere, method of moving part through furnace, the character of the processing equipment, and size of muffle cross-section. These and all the others are highly important because the mechanical properties attained, the tolerances that can be held, and uniformity of results all are determined by the degree in which the variables are controlled. Thus, the future of powder metallurgy as a production process depends in no small measure on how much is known about the variables, and how well they can be controlled.

In recent years considerable strides have been made in controlling the variables in metal powders. The uniformity and purity of powders has been improved so that the fabricator knows reasonably well what he is getting. However, the study of all the processing variables has really only begun. Relatively little is known about the effects that all the variables encountered during pressing and sintering have on final properties of various metal powders and on dimensional changes in the finished part.

More basic investigations of the sintering mechanism are particularly needed to provide data on the differences in sintering characteristics for different materials, and to determine the effects of critical small changes in time, temperature and atmosphere. Studies already made by a number of investigations have shown the importance of such work. For example, in one particular case it was shown that the tensile strength of a stainless steel powder could be increased about 1/3 by using a helium atmosphere instead of hydrogen.

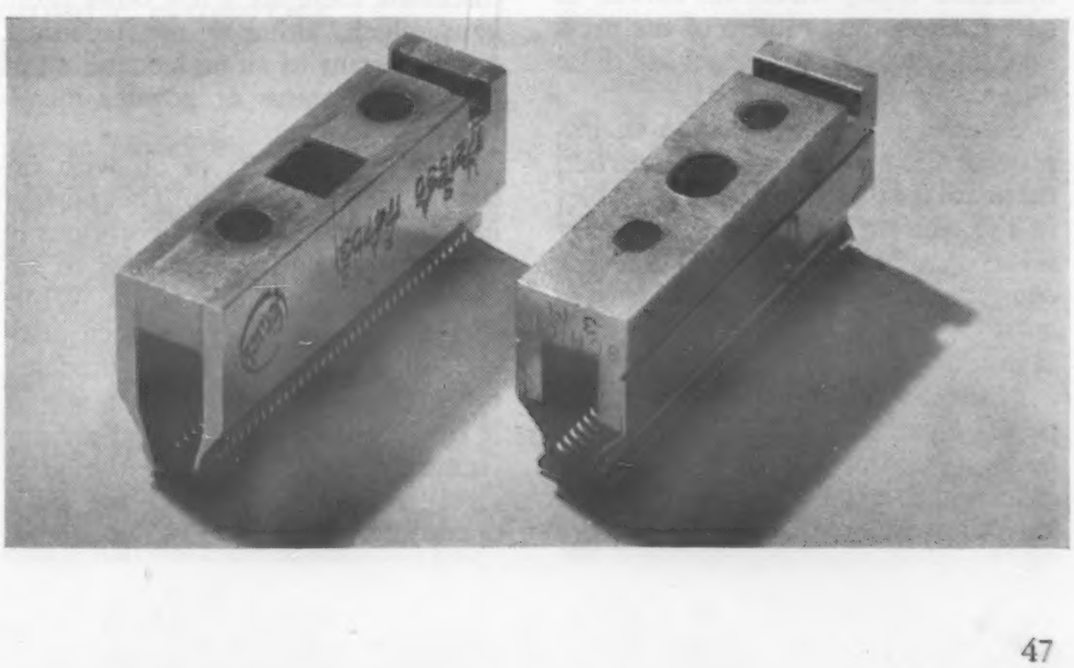
Standards and Specifications

One of the best ways of gaging the advance of a process or material is to watch the progress made in standardization and in establishing specifications and standards. While much work along these lines remains to be done, substantial progress has been made. For example, the specification on oil impregnated metal powder bearings (ASTM B202-45T) has been in use about four years and has served to reduce considerably the number of bronze-base and iron-base powders used for standard type bearings. It has also served to clarify the density and dimensional requirements for this particular metal powder application. Other specifications set up



A die and punch used for pressing metal powder compacts. (Courtesy: Westinghouse Electric Corp.)

This shearing head block for the Shick dry shaver was formerly made of three machined parts (left). It now consists of a metal powder part and a simple stamping (right).



by the ASTM and the Metal Powder Assn. during the past several years include a standard method of determining apparent density, a method of testing flow rate of "easy-flowing" powders, a method of sieve analysis, procedures for selecting samples from finished lots of metal powders, and a method of determining hydrogen loss of metal powders.

Both metal powder producers and fabricators through the Metal Powder Assn. and the American Society for Testing Materials are getting together at present to develop a number of other specifications that will be helpful to both the producer and purchaser of metal powders. The projects include the following: standards for green strength of metal powder compacts; methods for chemical analysis of metal powders; methods for determining flow rate of very fine powders; and methods of determining the size and quantity of sub-sieve particles in metal powders. This last project is quite important, for both the amount and size of sub-sieve particles affect mechanical and processing characteristics.

Equipment and Processing Developments

Equipment manufacturers up until recently have done little in the way of providing equipment specifically designed to meet the special requirements of powder metallurgy. This is rapidly being corrected, particularly in pressing equipment where at least one large manufacturer has set up a comprehensive development program.

The demand is, of course, for presses with higher pressures and faster production. Unfortunately, these two demands cannot always be satisfied. For high production rates, mechanical type presses are usually used, but where very high pressures are involved it is necessary to go to the hydraulic types, which are slower in speed. Thus, the problem of the press manufacturer is to reconcile these differences as best he can.

Sintering furnaces also can be improved upon. As pointed out earlier, there are a large number of variables in the sintering operation, including some directly related to the furnace equipment. For best results, furnaces must be designed giving due consideration to these variables.

Much has been heard during the past few years about hot-pressing, and nearly everyone agrees that it has tremendous advantages. Experiments have shown that when metal powders are pressed in a hot instead of cold condition, extremely high density parts are possible. Also, the pressing pressures required are much lower than those required for cold-pressing. Hot-pressing would also aid the expansion of the use of alloy powder parts. Many pre-alloyed powders require high pressures when cold pressed to attain their optimum properties. However, hot-pressing in many cases results in high properties at reduced pressures. While hot-pressing is being used successfully for making parts of high temperature powders such as tungsten carbide, it is still in the development stage for the other common powders. Before it can be used extensively on a commercial basis a number of problems must be solved. These include the prevention of oxidation during heating, elimination of excessive die wear, and working out means of rapidly heating dies and punches.

In recent years the possibilities of plating metal powder compacts has received considerable attention. Although it has been found that most metals which can be plated in wrought form can also be plated when in the form of a metal powder compact, the results are by no means comparable. There are inherent difficulties which still remain to be worked out before metal powder parts can be plated as easily and satisfactorily as the wrought forms.

Progress has been made in other directions—for example, heat treating. Ferrous powder parts are being successfully heat treated and case hardened to improve their strength and wear properties. And as was mentioned earlier, impregnation processes are being used to raise the performance characteristics of metal powder parts.

Some Nontechnical Problems

Besides the technical problems just discussed, there are a few other problems which, although not technical, are important to an understanding of the present status of powder metallurgy.

One of these has to do with exchange of information. The powder metallurgy field has been notorious in the past for its unwillingness to exchange technical information. While this may or may not have been justified, it has in many cases hindered the progress of the field as a whole. It is true that there no longer are any "trade" secrets concerning the principal metal powders and the basic operations of the process, but according to one prominent member in the field, there is still basic development work conducted by individual companies that, if published, would aid the field as a whole. One such case cited is that of basic research on aluminum powders.

Powder metallurgy has about reached the point where closer cooperation among powder producers, fabricators and users is essential to further expansion, and there are a number of signs that indicate progress in this direction. One of the encouraging signs is the increasing number of informal get-togethers where common problems are discussed and information exchanged. Another indication is the increased activity in establishing standards and specifications, as pointed out earlier in this article.

Finally, there is the problem of proper application of the process. Powder metallurgy has suffered probably more from over-application than from under-application. Some of its more outspoken and enthusiastic supporters have been inclined to talk of powder metallurgy as a cure-all. Many fabricators have taken on jobs that never should have been made by powder metallurgy. Consequently, there are numerous cases where parts have failed, either mechanically or cost-wise, and this has resulted in "black-eyes" to the entire field. Fortunately, more caution is beginning to be used. Its limitations are better known and the tendency is to use powder metallurgy only in applications where satisfactory performance is assured. However, there are some who feel that much more could be done to eliminate misapplications. There is no doubt but that the sooner the capabilities and limitations of powder metallurgy are more clearly defined and generally known the sooner it will find its rightful place in the industrial production picture.

Prices of Common Metal Powders

Metal	Cost per Lb.
Iron	8¢ to $1.00 +
Pre-Alloyed Carbon Steel	15¢
Copper (Electrolytic)	33 to 42¢
Brass	27 to 30¢
Bronze	50¢
Lead	28¢
Nickel	75 to 90¢
Aluminum	35¢
Stainless Steel	75¢ to $1.00 +
Tin	$1.30
Tungsten	$3.25
Cobalt	$3.00

How to Reduce Adverse Effects of Fabricating on Magnetic Properties of Steels

by J. E. RYAN, Control Engineering Div., General Electric Co.

A useful device for checking enamel thickness on laminations in core plate enamel tester

Annealing treatments and careful selection and control of fabricating techniques can go far in maintaining high magnetic properties in electrical parts.

• PARTS IN ELECTRICAL devices that make up the paths carrying magnetic flux usually have a twofold function: (1) They must have enough structural strength to withstand the electrical and mechanical forces encountered in service; (2) they must carry the magnetic flux efficiently. Based on the properties of materials used, the engineer can design to meet both these rquirements. However, manufacturing operations must also be considered; for just as fabricating methods can introduce unexpected stress raisers, so they can also impair the magnetic properties. Some of the adverse effects caused in manufacturing are unavoidable and must be allowed for in design or alleviated by later treatments. Others can be avoided completely if their causes are appreciated by both the design engineer and production supervisor.

Therefore, this article discusses the effects that some of the common processing methods have on magnetically "soft" materials and how they can be avoided or corrected.

Effect of Grain Direction

When steel is rolled, the grains are elongated in the direction of rolling. During subsequent annealing, the recrystallization may all but eradicate this distorted structure so far as the microscope shows, but the metal exhibits quite different magnetization characteristics with and across the grain. This is because the rolling lines up the atomic structure of all grains in substantially the same direction, and annealing does not materially alter its alignment even though completely new grains are formed. A typical silicon steel, for example, shows different magnetization and core loss characteristics for two different directions. In both respects, the cross-grain properties are generally inferior to those taken with the grain. Those for 45 deg. with the grain are better than the average between the two.

Designers of electrical equipment usually specify the desired grain direction in magnetic parts, particularly in laminated structures. The factory must be careful to observe this when designing dies and when cutting stock.

Cold Work and Strain Effects

Cold work of any sort impairs the permeability of magnetic materials. It also broadens the hysteresis loop. This, in turn, increases the heat generated in alternating current apparatus and the troublesome "sticking" effect sometimes experienced with armatures of contactors and relays.

The cold working effects may be produced throughout the material by such processes as cold rolling, drawing and forging; on the other hand, they may be produced only in limited regions by bending, shearing or machining.

Cold Rolling—The pronounced effect of cold rolling on the magnetization curve (*i.e.,* on permeability) is seen in Fig. 1. The trends are typical for all steels; for some of the very high permeability materials like Nicaloi and Mumetal, the effects are still more marked. Fig. 2 compares the hysteresis loops for the same materials. The larger loop for the cold-worked material is evident.

Thus, for magnetic purposes, a cold-worked steel may not be substituted for the same composition in the annealed condition, even though

the former may be superior from a structural or fabrication standpoint. However, suitable annealing after fabrication can restore the desired properties. This will be discussed in a later section.

Bending—Permanent deformation of the metal in the vicinity of a bend produces cold-working effects there which are similar to those illustrated in Figs. 1 and 2. In addition, reduction in cross-section usually occurring at a bend further lowers the flux-carrying capacity of the part. Cold work effects can be removed by annealing, but the reduction of area is overcome only by designing with generous radii.

Bending stresses well below the elastic limit also cause a marked decrease in permeability and some increase in hysteresis loss. The effect is greatest in the moderate flux density range (around 60,000 lines per sq. in. in steel). If the metal is annealed while being held in the strained shape, it recovers its unstrained properties.

Some investigators believe that much of the observed changes due to cold-working are caused by locked-up *elastic* stresses in the cold-worked material. In any case, the elastic stresses set up during fabrication and assembly cannot be taken lightly. One of the common causes of elastic bending is the clamping or riveting of wavy laminations into a solid stack.

Sheared Edge Effects—The metal adjacent to a sheared edge contains residual stresses, the effect of which will extend from 0.010 to 0.100 in. back from the edge, depending upon the metal thickness and the die condition. The inferior magnetic quality of this zone makes the part bounded by the sheared edges act, from the magnetic standpoint, as if it were somewhat narrower. This is most pronounced, of course, in narrow sections where the flux direction is parallel to the cut edge. Fig. 3 shows representative data for a 4% silicon steel sheet in the moderate flux density range where the effects are greatest.

When design is such that flux crosses a butt joint perpendicular to a sheared edge, the lowered permeability of the strained metal makes the joint act as if there were a large air gap there. Again, this "effective" air gap is largest at moderate flux densities.

For apparatus in which the lowest possible hysteresis and magnetizing current is demanded, annealing after shearing is required to erase these effects. However, use of sharp dies with proper clearances can keep them within reasonable limits in less exacting applications.

Pressure Effects—The clamping and riveting of stacks of laminations introduces large compressive stresses perpendicular to the plane of the sheets, particularly near the rivets. In fact, it is not unusual to have the rivets stressed to their tensile yield points in the finished assembly. Some idea of the resulting magnetic effects can be obtained from Fig. 4. The rings were tested under uniform transverse pressure. Note that the magnetizing current required for a given flux density is more than doubled by a pressure of 10,000 psi., a value which is often reached near the rivets. Such large pressures are usually not required to hold the stack against mechanical forces, but result from the large forces needed to upset the rivets properly. Anything that can be done to reduce these forces is beneficial to the magnetic properties.

Anealing to Improve Magnetic Properties

All magnetic materials which are basically low-carbon steels can have all adverse effects of cold work removed by heating to 1470 or 1560 F for about an hour, followed by a slow cool over a period of 10 hr. or so. This produces a true recrystallization and, in most cases, permeability will be slightly higher and core loss lower than in mill-annealed material as received.

Recommended Die Clearances and Maximum Burr Height for Silicon Steel

	Grade	% Silicon	Gage (and Thickness) No. 29 0.014 In.	No. 26 0.0188 In.	No. 24 0.025 In.	No. 22 0.031 In.
Clearance, In.	Armature	0.5	0.0005	0.00065	0.0008	0.0015
	Electrical	1.0	0.0005	0.00075	0.0009	0.0015
	Dynamo	2.5	0.0006	0.00075	0.0009	—
	Transformer	4.25	0.0007	0.00085	0.001	—
Max. Burr Height, In.	All	All	0.002	0.0025	0.003	0.0035

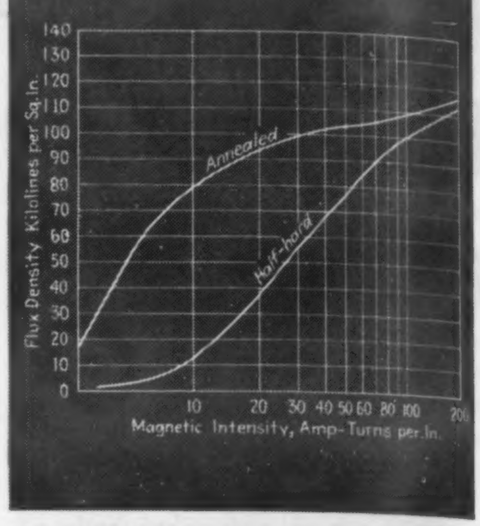


Fig. 1—Effect of cold work on magnetization curve of 0.10 carbon steel.

A less drastic treatment, with less danger of warping the parts, is a stress-relief anneal. Carried out at about 1200 F for an hour, followed by slow cooling, it removes the bulk of the cold work strains and thus regains most of the properties possessed before fabrication.

Excessive oxidation of parts being annealed may be avoided in a bell-type furnace by sand-sealing the edge of the bell and keeping the volume of parts fairly large with respect to the bell volume. It is particularly necessary to control the quality and thickness of the oxide on thin laminations so that the net iron section of the stack will not be excessively reduced. Also, thick, loose oxide does not permit a mechanically sound stack to be assembled.

For high permeability alloys such as Nicaloi, the annealing temperature should be between 1830 and 2010 F, held for 2 to 4 hr., and then slowly cooled. To guard against oxidation that would result at such temperatures, an atmosphere of pure dry hydrogen is usually used.

Parts often exhibit a tendency to stick together, especially when annealed in a reducing atmosphere at high temperatures. Dusting them with an inert refractory powder such as magnesia somewhat alleviates this.

Fabricating Techniques

Punching—the punching of plain low-carbon steel is a well-known pro-

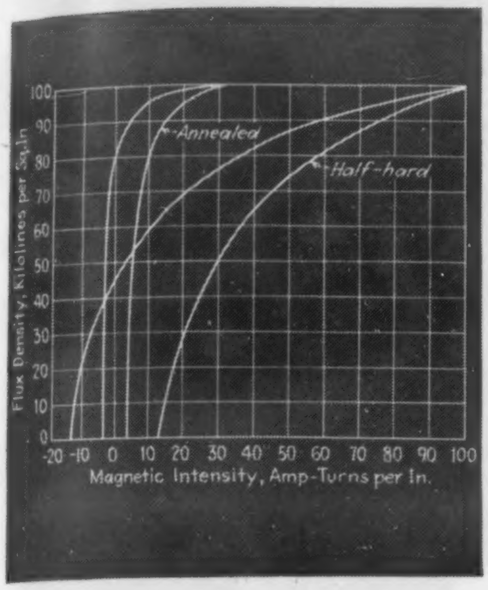


Fig. 2—Effect of cold work on hysteresis loop of 0.10 carbon steel.

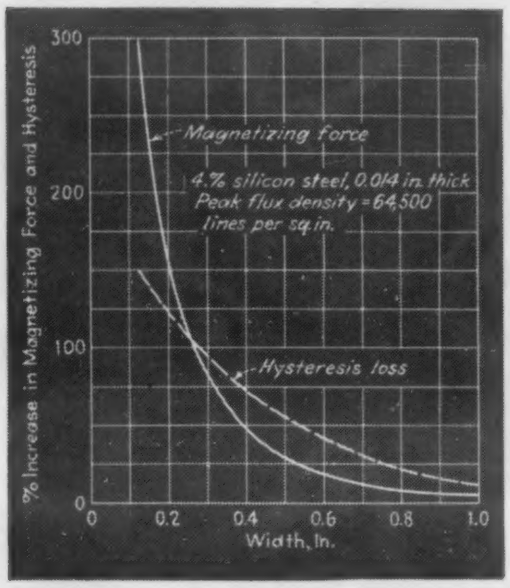


Fig. 3—Increase in magnetizing force and hysteresis loss due to sheared edge effect.

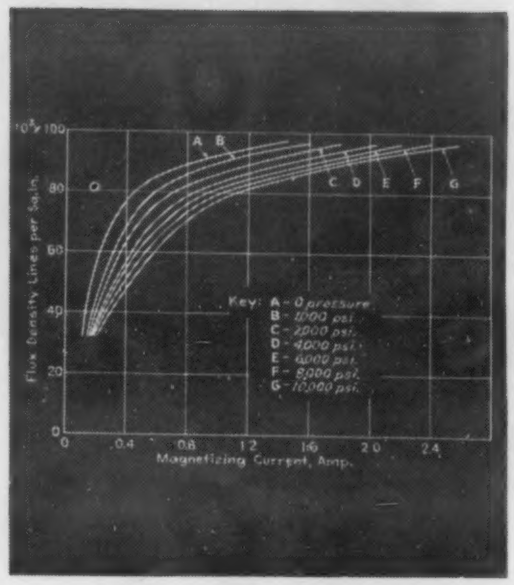


Fig. 4—Effect of clamping pressure on magnetization of silicon steel.

cedure. Silicon steel, however, presents some special problems. In the higher silicon percentages, it is brittle. Moreover, it has an abrasive surface, which increases die wear. To keep the burrs to a height that will not interfere with proper stacking of laminations or increase interlamination eddy current excessively, dies must be made with correct clearances and must be kept sharp. The accompanying table gives the clearance recommended for new dies by the Allegheny Ludlum Steel Corp. A relief taper of 0.001 to 0.002 in. per in. back from the cutting edge is recommended for all die surfaces.

The resinous core enamels which are furnished on lamination stock for superior interlamination resistance also serve as a die lubricant during punching. The mineral-filled core enamels, which are able to withstand annealing temperature, are very hard on dies; hence, they are not very widely used on mill-enameled sheets. A preferred practice on laminations which must be annealed after punching is to use stock that has been resinous-enameled at the mill. After punching, this enamel is burned off during anneal, then a final enamel coating of any desired type is applied.

Machining—The increase in hardness and brittleness with increasing silicon content makes extensive machining on steels with more than 1.25% silicon inadvisable. One machining operation that is peculiar to magnetic structures is the facing of abutting surfaces of laminated cores. These must be quite smooth and flat to produce a quiet magnet. Finishing is done by grinding, milling or broaching. Light cuts with sharp tools are essential to avoid burring and bending of laminations. Since the assembly is less rigid than solid metal, special care is required in clamping to avoid distortion after release.

Welding—The inert-gas shielded arc welding method has recently been applied to the assembly of laminated cores in place of conventional riveting. Small motors and solenoids using up to 2.5% silicon steel were among the first applications. No filler metal is added, and since electrode travel is mechanically controlled, a smooth, uniform weld results. Because the parts can usually be designed so as to keep all but a minimum of magnetic flux from linking the welds, stray eddy currents are virtually non-existent.

When spot or projection welded parts form part of a magnetic circuit, care must be taken to leave the joined surfaces close together over the entire joint area. Even though the weld area may be entirely adequate mechanically, an air gap in parallel with the weld introduces an objectionable reluctance to magnetic flux at all but the very lowest flux densities.

Some Inspection Methods

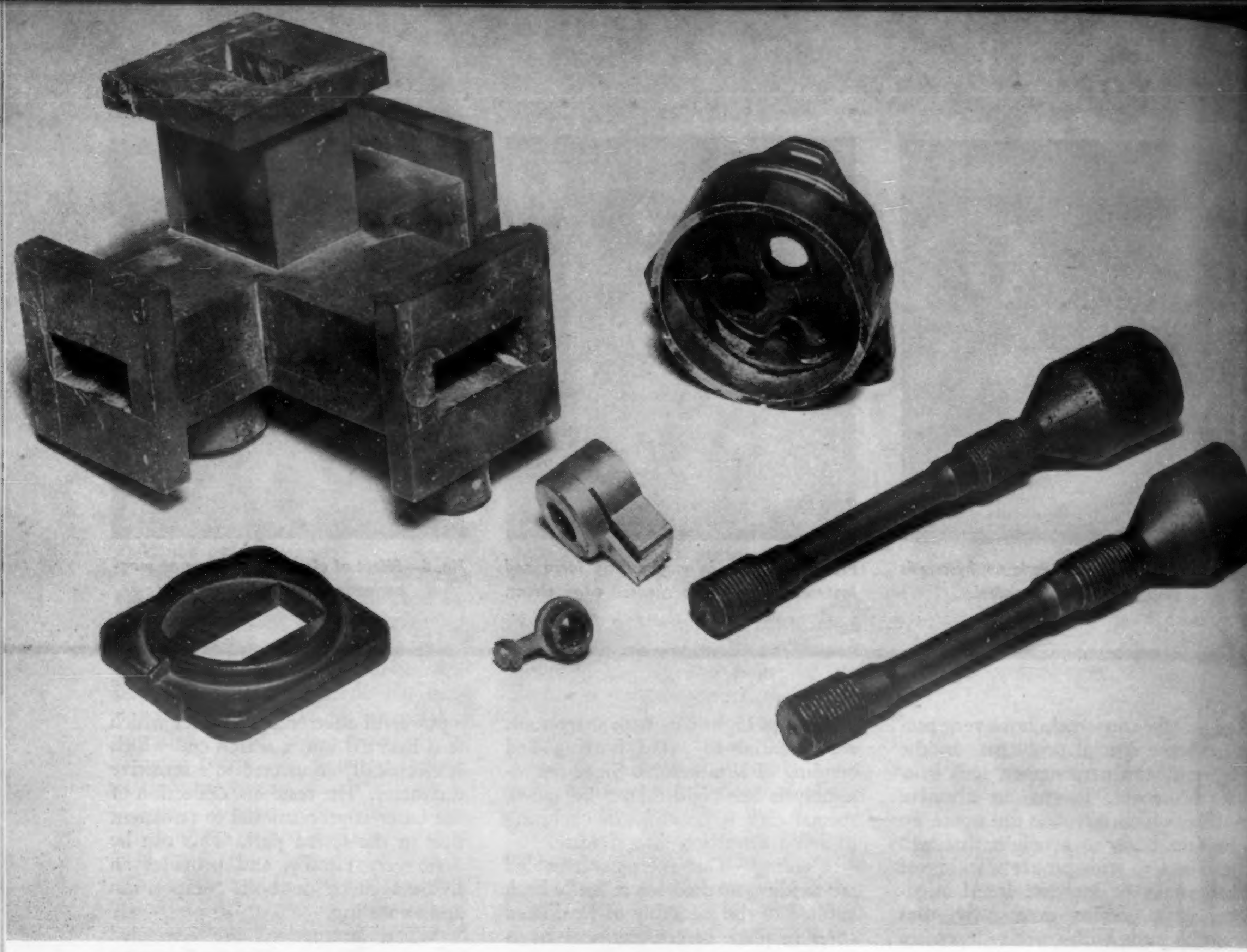
Besides the standard permeability and core loss tests made on samples of unfabricated magnetic material in the engineering laboratory, it is often desirable to check the finished part in the factory for a magnetic property.

The remanence test is often applied to parts of time-delay relays and the like wherein low remanence is essential. The part is first magnetized on a powerful electromagnet, after which it is inserted into a search coil which is electrically connected to a sensitive fluxmeter. The resultant deflection of the latter is proportional to remanent flux in the tested part. This can be done very rapidly, and provides an indirect check on both composition and annealing.

When laminations are enameled after punching and annealing, the control of enamel thickness presents a problem. If too thin, its resistance will be too low; if too thick, stacking space factor suffers. A useful device for checking single sheets is the core enamel tester. Basically, it measures the resistance between a row of hydraulically-loaded plungers and a lower platen, this resistance being due to the enamel film on the interposed lamination. Since it works on single sheets of almost any shape and is self-contained, it is well adapted for use on the production line.

References

1. Spooner, T., "Properties and Testing of Magnetic Materials," McGraw-Hill Publishing Co.
2. Barton, J. P., "To More Efficiently Fabricate Electrical Sheet," *Electrical Manufacturing*, Apr. 1941.
3. Technical Bulletin EM-1, Allegheny-Ludlum Steel Corp.
4. "USS Electrical Steel Sheets," Technical Bulletin No. 1, Carnegie-Illinois Steel Corp.
5. Franklin, R. F., "Measurement and Control of Interlaminar Resistance and Laminated Magnetic Cores," *A.S.T.M. Bulletin*, Jan. 1947.



A group of typical precision castings made using frozen mercury patterns.

New Precision Casting Process Provides

By using frozen mercury patterns in place of wax, highly accurate aluminum and stainless steel precision castings are produced; here is one of the first complete descriptions of how it is done.

• ONE MORE CASTING PROCESS has been adopted by the Sperry Gyroscope Co. plant at Great Neck, N. Y., in its constant attempt to produce castings which must meet exacting specifications. The latest process is a variation of precision casting in which frozen mercury replaces the wax most generally used in investment casting. This method is patented and is known as the Mercast process.

Although most castings in this range of sizes and alloys produced by Sperry are made by the wax investment method, the Mercast method is being applied more widely as experience is gained in its use. The use of frozen mercury offers greater dimensional accuracy, superior smoothness and accuracy of detail. Some stainless steel and coin silver castings have been made by Sperry by the Mercast process, but most of the castings have been of Alcoa 356 alloy.

For the Mercast process, pattern making and investing are altered from procedures used in conjunction with wax investment materials. Such changes are necessary because of the different materials involved. For instance, since mercury freezes at -40C (-40 F), a pattern made from it must be chilled to below this temperature to solidify and hold its shape until investment is completed.

by HERBERT CHASE, in collaboration with LESLIE T. SCHAKENBACH, Precision Casting Engineer, Sperry Gyroscope Co., Inc.

Three-piece mold in which the frozen mercury pattern for the aluminum casting at lower left was made. The investment containing several duplicate cavities is shown back of the molds.

Better Finish, Closer Tolerances

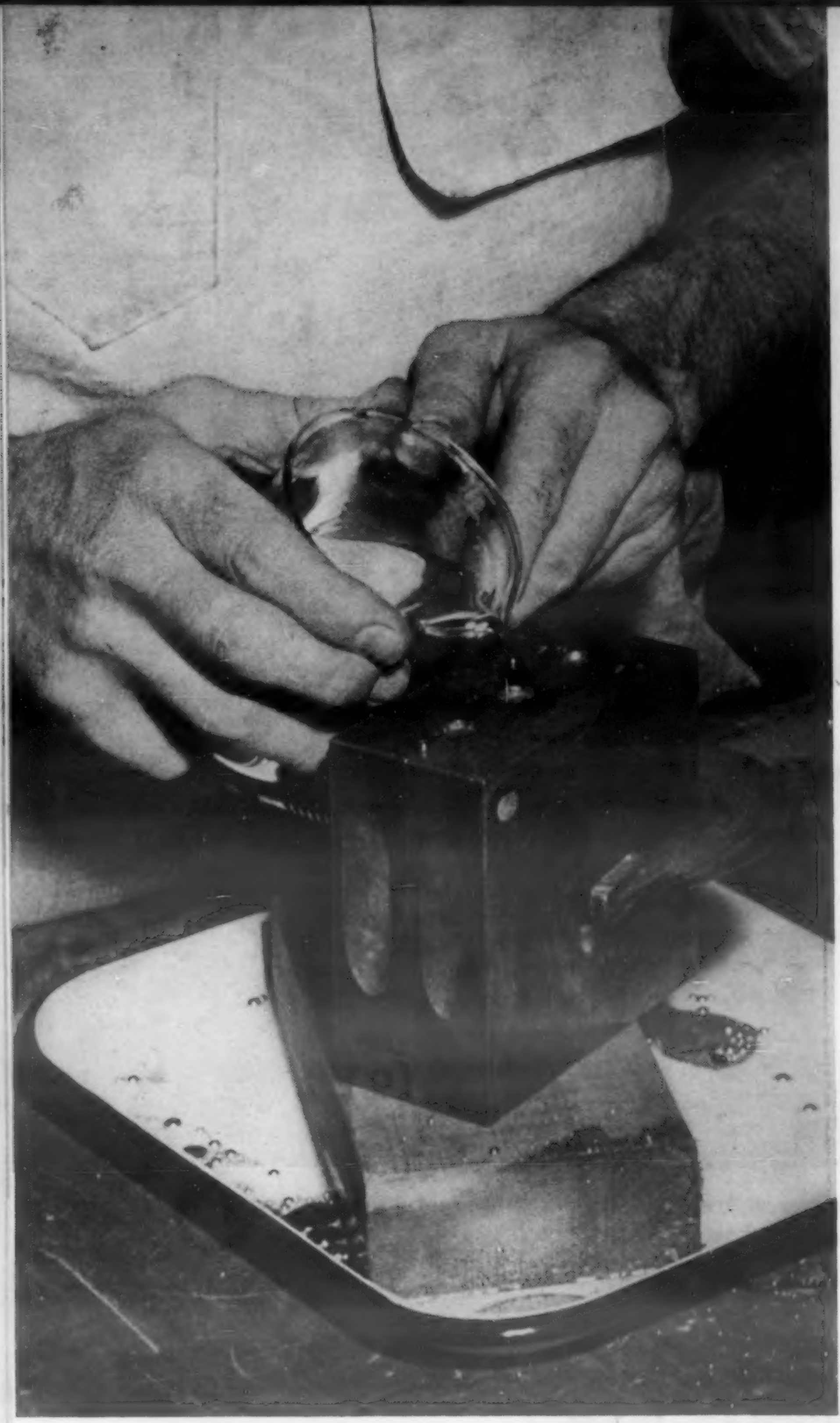
The Mercast process as carried out at Sperry follows:

The mold for making the pattern is built much the same as for wax but with a different allowance for shrinkage and with a sprue hole or holes formed within the mold in place of the injection opening used for wax. When assembled, the mold is placed on a bench and is first filled with acetone, which acts as a lubricant. Then mercury at room temperature is poured into the mold from a beaker and displaces the acetone. Mold joints are tight fitting and prevent any mercury leakage, of course.

When thus filled, the mold is placed in a cold tank for freezing. This tank has 10 in. of cork insulation on the sides and 12 in. on the bottom. The top is open along two sides of a central box containing dry ice, but this box is kept covered. The box, which is of stainless steel, has its lower portion immersed in methlylene chloride to a depth of about 24 in., the liquid being under as well as around the box and having a depth of 28 in. around the box. This liquid is non-flammable and non-toxic, and is chilled by the dry ice in the box to -60 C (-76 F).

In this cold liquid, the mold is nearly submerged, resting on a platform, until the mercury freezes. A bent wire rod placed in the sprue hole freezes in the mercury and provides a convenient means for handling the pattern. As the mercury contracts somewhat in freezing, more mercury is sometimes added while freezing proceeds. Suitable allowance is made for the shrinkage of the metal to be cast, of course, in designing the mold but no shrinkage allowance is required for the mercury itself. In general, it takes about 10 min. for the pattern to freeze. The mercury pattern reproduces sharply all mold details. Then the mold is opened by an operator using gloves while the mold rests on a wooden platform that is barely submerged in the refrigerant.

As the pattern, which looks like and is about as hard as lead, must be kept frozen and free of moisture condensed from the atmosphere, each pattern is immediately submerged, suspended from the wire handle until ready for investing, which is done in another cold tank. This tank is also cooled by dry ice but containing no other refrigerant. In a larger tank



Filling an assembled mold with mercury at room temperature. The mercury displaces acetone, which acts as a lubricant.

After the mercury pattern is frozen in the cold tank, it is removed from the mold and hung in this chilled bath until ready for investment.

are small containers for the liquid investing slurry, which is kept at about -60 C (-76 F) or well below the freezing point of the mercury.

When dipped in the slurry (Crytobalite), the pattern, held by the wire in gloved hands, is tilted and turned until all surfaces are coated. Then the pattern is left to drain for about 15 to 30 min., during which other patterns are being similarly coated. Thereafter, the pattern is redipped several times at about 15- to 30-min. intervals until a satisfactory thickness of coating is built up.

In general, 8 to 12 dips are enough to provide a shell of sufficient strength, say from ⅛- to ¼-in. average thickness. If, especially for large molds or those to be cast centrifugally, greater mold strength is desired, the shell formed by dipping can be set in a supporting investment in a flask before baking is done.

The mix used in the dipping investment includes solid refractory ingredients, and the smoothness of the inner wall of the investment (which contacts the metal to be cast) affects the smoothness of the casting. For greatest smoothness, the pattern must be smooth and the refractory particles as small as feasible. At Sperry, refractories that pass a 500-mesh screen are used but those passing 1000 mesh are available.

When the dipping investment is complete, the mold thus formed is placed on a bench where heat is absorbed from the atmosphere. This results in the mercury becoming liquid and it flows out and to the drain hole at the center of the bench, passing thence through a water seal into a container from which the mercury is passed through a cleaning cascade. The mercury is thus cleaned of any refractory or impurities and is collected in bottles for reuse.

As the mercury never attains a temperature above that of the room and is never touched by hands, the chances of mercury poisoning are considered negligible. This conclusion was reached after careful consideration by insurance and other authorities. Nevertheless, there are exhaust vents around the mercury bench and mercury vapor indicator alarms are provided, especially near the mold baking ovens. No indication of any mercury vapor has ever been found, and any vapor coming

Dipping a frozen mercury pattern in the investment mix, which is kept chilled to −60 C (−76 F). After investment solidifies, mercury melts at room temperature and runs out.

from the small amounts of acetone used is quickly exhausted by the ventilating system.

When the molds are free of mercury, they are dried at 90 C (194 F), are fired at about 1030 C (1886 F), and then cooled to the temperature best suited for the alloy to be cast in the molds, much as for molds made with wax patterns. Casting is also done with the same equipment. Advantages attained with the mercury patterns include smoother surfaces, less pattern distortion, ability to attain sharper corners and thinner sections at edges, ability to hold significantly closer dimensions, and feasibility of using larger patterns than for those made in wax. Important results include more precise dimensions and smoother surfaces on castings if pattern mold cavities are polished sufficiently.

Close Dimensional Limits

With the Mercast process in this plant, dimensional limits have been held within ±0.003 in. for dimensions up to 1½ in. and, on some smaller dimensions, limits as close as ±0.001 in. have been held at certain critical points in making aluminum castings. It does not follow, of course, that these very close limits apply to all dimensions or to all castings, even at critical points. The closer the dimension specified under ±0.003 in., the higher is the reject rate. Other factors, such as the shape and size of casting, wall thickness and care in all phases of the processing affect the results that have been secured.

In general, however, the Mercast process has been found to enable closer control on critical dimensions than when wax patterns are used. Thus far, processing has been somewhat slower and costs somewhat higher than where wax has been used. But, as yet, experience with the Mercast process has been quite limited. Further experience may alter to some extent such conclusions as have yet been drawn.

Casting of investment molds is substantially the same for both types. Most Mercast and all lost wax molds are cast centrifugally and all melting for both types is accomplished in induction furnaces of the Ajax Electrothermic type operating at 3000-cycle frequency. Two furnaces of 50 kva.

and two of 20 kva. are available. The larger ones, more recently installed, are intended especially for ferrous metals and the smaller for nonferrous, but either type can be used for either ferrous or nonferrous metals.

Centrifugal casting is done with either a single mold or with four molds set in suitable carriers with arrangements for pouring metal at the rotation axis. Where four molds are used, they are clamped against a refractory block having a central hole from which runners radiate to each mold. Mercast molds are set in a reinforcing base when centrifugal casting is to be done. When a single mold of either type is mounted eccentrically for centrifugal casting, a counterbalance is required, of course.

Centrifugal castings tend to be dense and require no risers, hence yield is high. It is possible, however, to pour into static molds and still produce satisfactory investment castings for some purposes if proper gating and correct casting methods are used. Only sound castings are permitted in Sperry applications. As investment molds are nonporous, care to avoid trapping air is essential. Moisture in the mold must be avoided, as any steam formation may result in pockets or in porous and defective castings.

As most castings are produced in short runs, melts are not large. Fast and convenient melting is attained, however, with the induction furnaces and they require no stacks, as no products of combustion are produced. The temperature of the melt is always taken and is held at the optimum level for the particular alloy used.

After castings have cooled, molds are broken by the use of a pneumatic hammer in a booth, from which dust is exhausted. Broken mold fragments fall through a grating, and castings are dropped in a water tank where any remaining investment is softened. Gates are then sawed off and castings are ready for blasting.

As a rule, surface finish on die castings parallels closely that on die cavity walls, which generally are polished.

Nearly all castings, whether made in dies or in investment molds, are blasted with steel grit but, on magnesium alloys, nonmetallic grit is used. In either case, a matte surface is left as a result of blasting.

In all cases, the surface finish would be classed as "smooth" and is superior to that attainable in sand castings. Although smoothness of a reasonably high order is required, simply for appearance reasons, on exposed surfaces that are not to be machined, smoothness on critical surfaces, especially those that must mate with other parts without machining, is often of much importance. In fact, the casting methods here described are often used primarily because they save a great deal of machine work that would be necessary if either sand cast or forged products were used.

Most precision castings require a high degree of smoothness even on interior surfaces, as cast, partly because machining of some of these interior surfaces is not practical and yet the surfaces must be free from scratches, tool marks or other imperfections besides being held within close dimensional limits. Castings produced by the Mercast process meet these exacting requirements and are the only type of cast or other product that has been found to do so in Sperry practice.

One of the centrifugal casting machines with cover raised after pouring of metal into whirling investment has been completed.

Three-Dimensional Forming of Acrylic Plastic Sheets

Acrylic plastics can be formed into a variety of compound shapes by methods ranging from manual and mechanical means to vacuum and air pressure methods.

by W. W. FARR, Supervisor of the Technical Laboratory, Rohm & Haas Co.

• THERE ARE MANY methods and combinations of methods for forming compound shapes out of acrylic plastic sheets such as Plexiglas. These include the following: manual stretch forming; mechanical stretch forming or yoke forming; slip forming; grease forming; plug and ring forming; free blowing or vacuum forming; vacuum snapback forming; vacuum drawing or blowing into a mold; ridge forming; and, male and female forming. In all these methods the compound shapes are formed by literally stretching the heated material to the required contour.

Stretch Forming

If the compound curvature is not excessive and the number of parts to be made does not warrant setting up elaborate equipment, it is often practical to stretch the heated plastic sheets over a form by hand. The sheet is heated to approximately 250 F, and a number of wooden carpenter's clamps are fastened to the edges, 6 to 10 in. apart.

Holding the plastic by means of these clamps, the forming crew draws the sheet down over the form. For some shapes, one edge of the sheet can be clamped to the form with carpenter's clamps, anchor clamps, vice clamps, or C-clamps, and the sheet stretched over the form from the other edge. When the sheet is stretched, a metal ring can be clamped in position around the edges, leaving the crew free to work on other forms.

As many as 10 men may be required for this manual stretching—the number depending upon the size and thickness of the piece and the extent of the stretch. Care must be exercised to keep the stretching of the sheet as uniform as possible. Slow, steady pressure should be exerted to allow the Plexiglas to stretch gradually.

Where compound curvature is not excessive, but where a considerable number of parts is to be made, it is practical to provide some mechanical means for stretching the plastic. For example, the heated sheet can be clamped in a yoke which grips the sheet outside the final trim line and then pulled down around the form by means of screw clamps, screw jacks, air or hydraulic pressure devices, or other mechanical means. To help keep mark-off to a minimum, the lowest pressure which will form the sheet should be used.

In some cases, the male form is mounted on the ram of a press and forced down through a stationary yoke. In other cases, the yoke is mounted on the press and the male form is kept stationary. The choice of method will depend on the equipment at hand and the particular shape being formed.

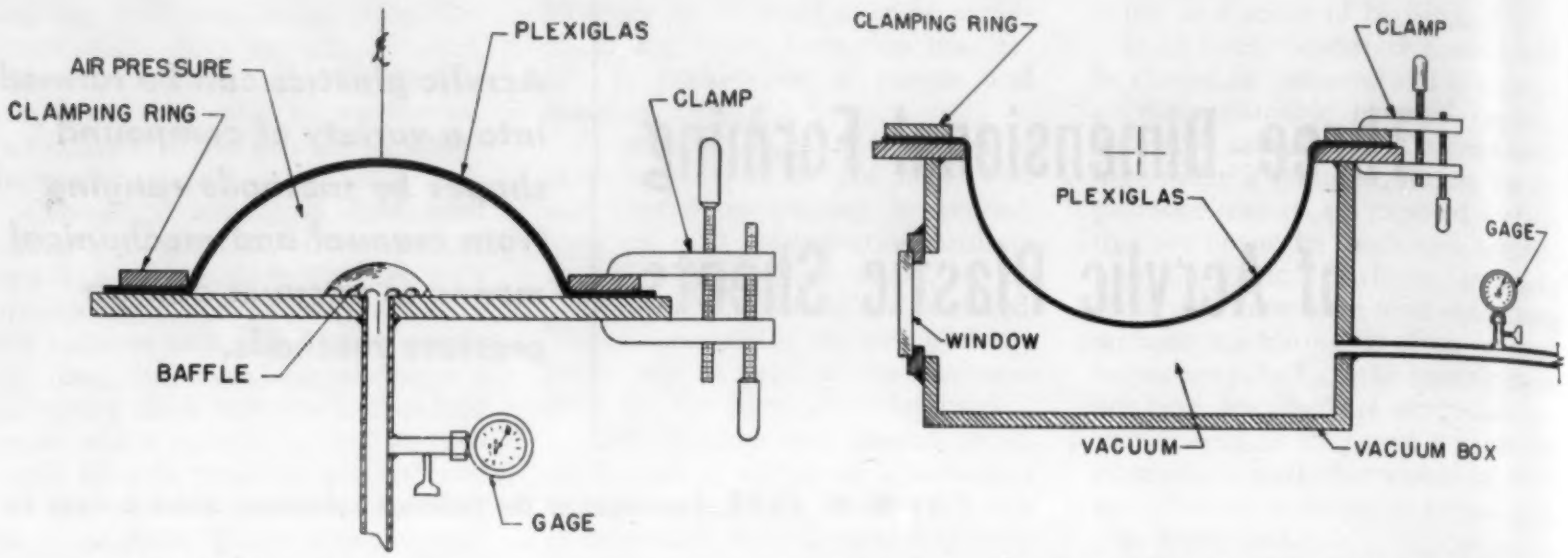
The hot sheet must be clamped in the yoke quickly and held under uniform pressure. Often it is clamped between two rings held together by manual or air-operated toggle clamps. Sometimes one of the two rings is fixed and the sheet clamped or released by moving the second ring. It is also possible to clamp the hot sheet between two fixed rings by means of a flexible air or hydraulic hose which can be inflated or filled to exert the required pressure. The yoke tends to equalize the stretching around the edge of the piece and produces, in general, more uniform thinning out than that found in parts stretched manually.

A modification of yoke forming is called slip forming because, during the forming operation, a pre-determined amount of material is allowed to slip through the clamping ring or yoke to reduce thinning out of the sheet. Wrinkles, which tend to form at the ring around the edges of the piece, limit the amount of material which can be allowed to slip through the ring. When sufficient material has been allowed to slip in, the rings are clamped more tightly together and the draw completed. Mechanical means of clamping the sheets are especially useful in slip forming. Various devices to limit the amount of material slipped-in, and hot clamping rings to avoid chilling the material, can be developed to suit special forming problems.

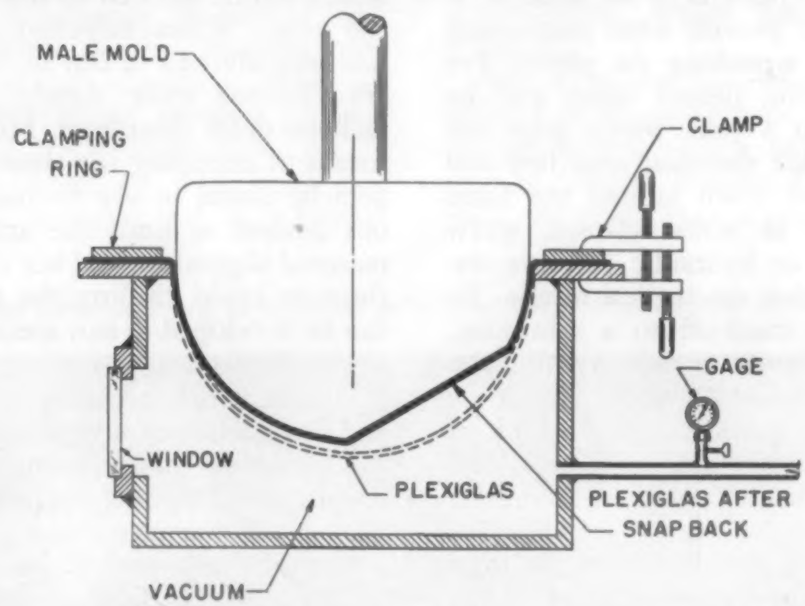
All the work necessary to stretch and slip the heated sheet is performed by the male mold acting directly against the hot, soft surface of the plastics. If the compound curvature is not too great, such action will not be too harmful. In deep-drawn sections, however, severe mark-off and optical distortion will result unless particular attention is paid to the surface and covering of the mold.

Grease Forming

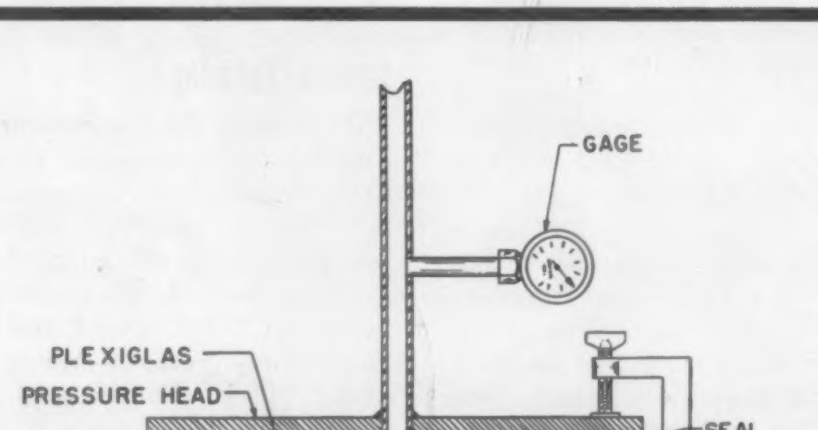
To correct the limitations of slip forming, it is possible to apply a heavy layer of suitable grease or other lubricants to the mold surface. The best parts are produced by the grease forming method when the form is heated to 125 to 140 F and the surface of the grease is heated to well over 200 F. Forms used in this method should be made of phenolic casting resin with a Fiberglas or shredded asbestos filler, or other material which will withstand repeated heating and cooling. Since metal molds hold their heat so long that the formed plastic parts are apt to distort when removed from the form, such forms are often cored so they can be cooled quickly.



Vacuum forming (left) and free blowing (right) methods permit rapid production of parts having high optical qualities.



Vacuum snapback forming, a variant of vacuum forming, is used where the desired part varies from a true "surface tension" shape.



The vacuum drawing or blowing into a mold method is used for parts of radically varying contours.

In general, the temperature of the sheet should be higher (from 300 to 325 F) for grease forming than for other forming. When a male form is used, it is covered with a felt blanket impregnated with a high soap content, petroleum grease. The blanket or cover must be carefully conditioned to remove all knots or hard spots and must be thoroughly impregnated with the grease. No pockets of grease should be allowed to accumulate under the cover. The form and cover are then coated with a layer of grease from 1/16 to 1/8 in. thick. After smoothing, it is heated until the surface film of grease is liquid and actually smoking hot. Infra-red or heat lamps can be used to heat the grease.

The heated sheet is stretch formed, usually by mechanical means, over the form. The grease film should appear uniformly liquid and mobile under the surface of the hot plastic sheet. After forming, the sheet is clamped in place and allowed to cool on the form.

After forming, it is necessary to wash the grease from these formed pieces. Unleaded gasoline, safety solvents or naphtha can be used. After the solvent wash, the parts should be washed in warm water with soap or wetting agents.

Grease forming has made possible the production of some compound curved sections other than free-blown shapes where good optical properties are required. It should not be applied to run-of-the-mill fabrication where the optical characteristics are not important but where cost is an important factor.

Plug and Ring Forming

In stretch forming, it is not always necessary that the heated sheet be clamped in a yoke or ring. A modification, known as the plug-and-ring method, operates on a principle similar to the familiar embroidery hoop.

The hot acrylic sheet is placed over the plug, a male form made to the inside contour of the finished part, and a single ring brought down over it. The ring is made to fit over the outside of the male form or plug, with allowance, of course, for the thickness of the sheet. The material can be drawn in this way even deeper than the smallest dimension of the ring opening, before it starts to wrinkle. The fact that it will eventually wrinkle is also of interest to the fabricator for, by using a larger ring or a smaller plug, dish shapes with wavy edges can easily be produced.

In its usual form, however, plug-and-ring forming has the disadvantage of producing excessive mark-off, usually at the inside corners of the formed part where it is most difficult to remove. For sections where optical properties are not important or for forming colored or translucent sheets, however, this disadvantage is not important.

Free Blowing or Vacuum Forming

For certain three-dimensional shapes, it is possible to form acrylics entirely by the use of air pressure differentials — vacuum or positive pressure — without the use of male or female forms. This method permits the rapid production of parts having extremely high optical qualities.

In practice, the heated sheet is simply clamped over a vacuum pot or pressure head and drawn or blown to shape. Since the sheet does not come in contact with any mold, there is no possibility of mark-off. Further, when an air pressure differential does the work of forming, the manpower required is reduced, and cooling is relatively uniform because both surfaces of the plastics are exposed to air. A large number of identical or different shapes can be blown or drawn in one operation and later cut into individual parts.

When the opening in the vacuum pot or pressure head is circular, the finished part approximates a section of a sphere for shallow-drawn parts. However, since the center of the sheet stretches first, this area thins out first and therefore cools first. The thicker areas around the sides and the circumference continue to stretch since they are still hot and plastic. Thus, in the case of deep draws, a bulging or fish bowl shape is produced.

Even if the opening of the vacuum pot is square or triangular, the material tends toward a spherical shape, since a sphere has the smallest surface area for any given volume. The resultant shapes are often called "surface tension" or "natural" shapes.

It is possible to increase the number of shapes which can be fabricated by differential air pressure by altering the shape of the pot opening in the third dimension. This device is sometimes desirable since it materially reduces thinning out of the sheet. This thinning out, incidentally, is not always undesirable either optically or mechanically in free-blown parts.

The choice between the use of vacuum and positive pressure in forming will usually depend upon the equipment at hand. In general, vacuum forming is preferred because it is safer, easier to control and simpler to seal. Also, when the hot acrylic is drawn into a pot, the danger of stray drafts of cool air chilling it unequally during forming is eliminated. There are some cases where the pressure differential possible with vacuum (14.5 psi. maximum) is not sufficient and positive pressures must be used.

Vacuum Snapback Forming

Where the desired part varies from a true "surface tension" shape, it is often possible to form the part by the so-called vacuum snapback process. This method is based on the tendency of hot formed sheets to return to their original flat sheet form, a tendency known as elastic or plastic memory.

Snapback forming is a variant of vacuum forming and is also done in a vacuum pot. After the heated sheet is drawn into the pot, a male form which reproduces the inside contour of the desired part is lowered inside the bubble formed by the sheet. Since the sheet is still hot, it has a tendency to resume its flat sheet form. Therefore, as the vacuum is gradually released, the material "snaps back" slowly against the form. The movement of the soft sheet after contact with the form should be kept to a minimum in order to avoid mark-off.

In this process, all stretching is done by pressure differentials and is therefore relatively uniform. Instead of being drawn across a form, the sheet is stretched before it comes in contact with the form, and the part is therefore relatively free of surface optical defects.

In snapback forming, the sheet will not snap back into reverse curves and will not follow rapid changes of contour very accurately. Nevertheless, it is possible to obtain closer contour tolerances in snapback forming than in free-blowing or vacuum forming. Specifically, tolerances of ± 1/8 in. are possible, as opposed to 1/4 in. or even 1/2 in. for some vacuum formed or free-blown parts.

Contour tolerances, however, are not always important in the type of part formed by air pressure differentials. In these methods, a flange integral with the formed part and at least 3/4 in. wide is formed where the part has been clamped to the vacuum pot. This flange provides a strong and simple method of mounting, and the contour of the flange can be held to fairly close tolerances regardless of the tolerances maintained on the rest of the part.

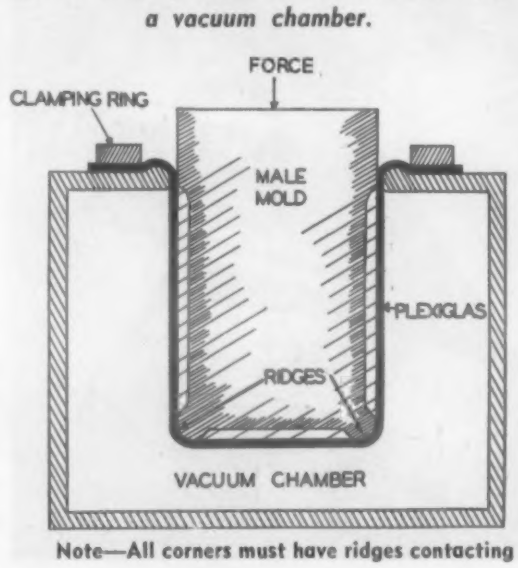
Vacuum Drawing or Blowing into a Mold

In still another method based on air-pressure differentials, the heated acrylic sheet is clamped directly to the edges of a female mold, and is either drawn down by vacuum or forced down by air pressure into the mold.

When the shape closely resembles a "natural" or "surface tension" shape, parts formed by this method will have fairly good optical parts. Under these conditions, every part of the sheet comes in contact with the mold at approximately the same time, and the pressure can be controlled so that mark-off is held to a minimum.

When the shape desired is not a

This method of ridge forming involves the use of a male mold in combination with a vacuum chamber.



Note—All corners must have ridges contacting

"surface tension" shape, one section of the sheet comes in contact with the mold before the other sections are fully drawn, and the pressure at the areas in contact with the mold will be great enough to cause surface defects.

If optical properties are important, it is necessary to use grease or other lubricant between the heated sheets and the mold, just as in grease forming. Special synthetic greases that do not change their viscosity radically with changes in temperature have been used successfully when this method was employed. The mold is warmed with electric elements, infrared lamps, steam or oil to approximately 150 to 180 F and then coated with a film of heated lubricant approximately 1/16 to 1/8 in. thick. This film must be reasonably uniform. It should be smoothed out, and fresh hot grease added as needed, between each forming operation. Vent passages are provided at the point where the hot plastic touches the mold last.

Molds for this method should be well-made of sturdy materials and adequately reinforced. Where the mold is greased, the use of positive air pressure is recommended. Vacuum tends to draw entrapped air from the pores of the mold, causing bubbles in the grease layer and distortions in the formed part. When the mold is not greased, either positive pressure or vacuum may be used. Molds for use with vacuum should have outlets at the points of deepest draw and should

The plug-and-ring principle is used to form letters in white translucent sheet.

provide for a tight seal between flange and sheet to avoid air leaks.

Vacuum drawing or blowing into a mold is used more often for forming parts which differ quite radically from "surface tension" shapes, but in which mark-off is not objectionable. In fact, the method can be used to reproduce in the plastic any pattern or device in the female mold. Very close detail can be picked up in this way, depending on the amount of pressure used. Very nearly geometric shapes can also be produced. Corners will, of course, tend to be round, the radius depending on the pressures used.

Ridge Forming

It is possible to form many compound shapes against skeleton or relieved molds. In this method, the sheet comes in contact with the form in very limited areas. The balance of the part does not come in contact with the mold and is free of mark-off. The method is applicable to a wide variety of parts, and often results in more uniform thickness within the part than is possible with other compound forming methods.

In some cases, the skeleton mold alone stretches the sheet, and the equipment and technique is quite similar to that used for mechanical stretch forming. Because the hot plastic tends to revert to its flat shape, the areas between "ridges" in the form or between ridges and the clamping ring are stretched taut. If a skeleton box is used as the mold, for example, the areas corresponding to the sides and bottoms of the box are plane surfaces. In other shapes, where the ridges are curved, the intervening areas tend to be concave.

Therefore, skeleton molds are often used in combination with air pressure differentials, particularly if the depth of draw is more than 3 or 4 in. Vacuum can be used not only to assist in stretching the sheet but also to produce flat or convex shapes between curved ridges.

The principles of ridge forming can be extended to both male and female molds so that reverse curves, flanges and flutes can be formed with a minimum of distortion. By using movable elements in the female mold, such devices can be formed on the sides as well as the base of the formed part.

By dividing a vacuum box with partitions and having separate control valves in each compartment, it is possible to vacuum form several shapes in a single piece. The plastic itself forms a seal when it is draw against the ridge or partitions. Air pressure can be used in the same way by using pressure heads which seal against the female around the edge. The ridges leave an obvious line in the formed part which serves as a guide to cutting its individual shapes.

The pressure differentials which may be used with these methods are limited, however, by the tension in the sheet as it is stretched across the dividing partition or ridge. A more positive seal can be made if ridges in the male mold press the sheet against corresponding grooves or ridges in the female.

Molds for ridge forming should be constructed with generous radii (at least twice the thickness of the plastic) at the edges and more at the corners, to reduce the possibility of tearing. Phenolic laminates, Masonite Die Stock, and wood are good materials for forms. Their low thermal conductivity prevents too rapid chilling of the hot Plexiglas. Where a minimum of thinning out is desired in deep drawn parts, the form can be constructed of pipe (chromium plated or smooth stainless steel) through which very hot water (180 F) can be circulated. These hot pipes keep "sharp bend" sections of the sheet softened so that material can easily slip past the ridges.

Male and Female Forming

It is very seldom necessary or even desirable to form acrylic plastics between matched male and female dies except where material must be made to flow, as in surface molding and embossing. Contact with even polished molds will mark the surfaces of hot plastic. Since, in male and female forming, both surfaces of the sheet are in continuous contact with molds, the possibility of mark-off is double that of other methods.

Even in forming parts where optical properties are not important and mark-off not objectionable (*e.g.*, forming patterned, translucent, and dark colored material), other methods may be preferable. Matched male and female dies usually cost more than tooling used in other methods. They should be metal to withstand the unequal pressures which may be encountered because of thickness variation in the sheet. If used cold, metal dies will chill the sheet; if used hot, they will prolong cooling time. These dies, therefore, should be cored to permit heating and cooling—which further increases cost of the dies.

Radiant Heating and Automatic Hydraulic Bending Combined to Form Steel Links

Links for farm equipment are produced rapidly and economically by a method that requires only a single heating of the bar stock for bending and hardening operations.

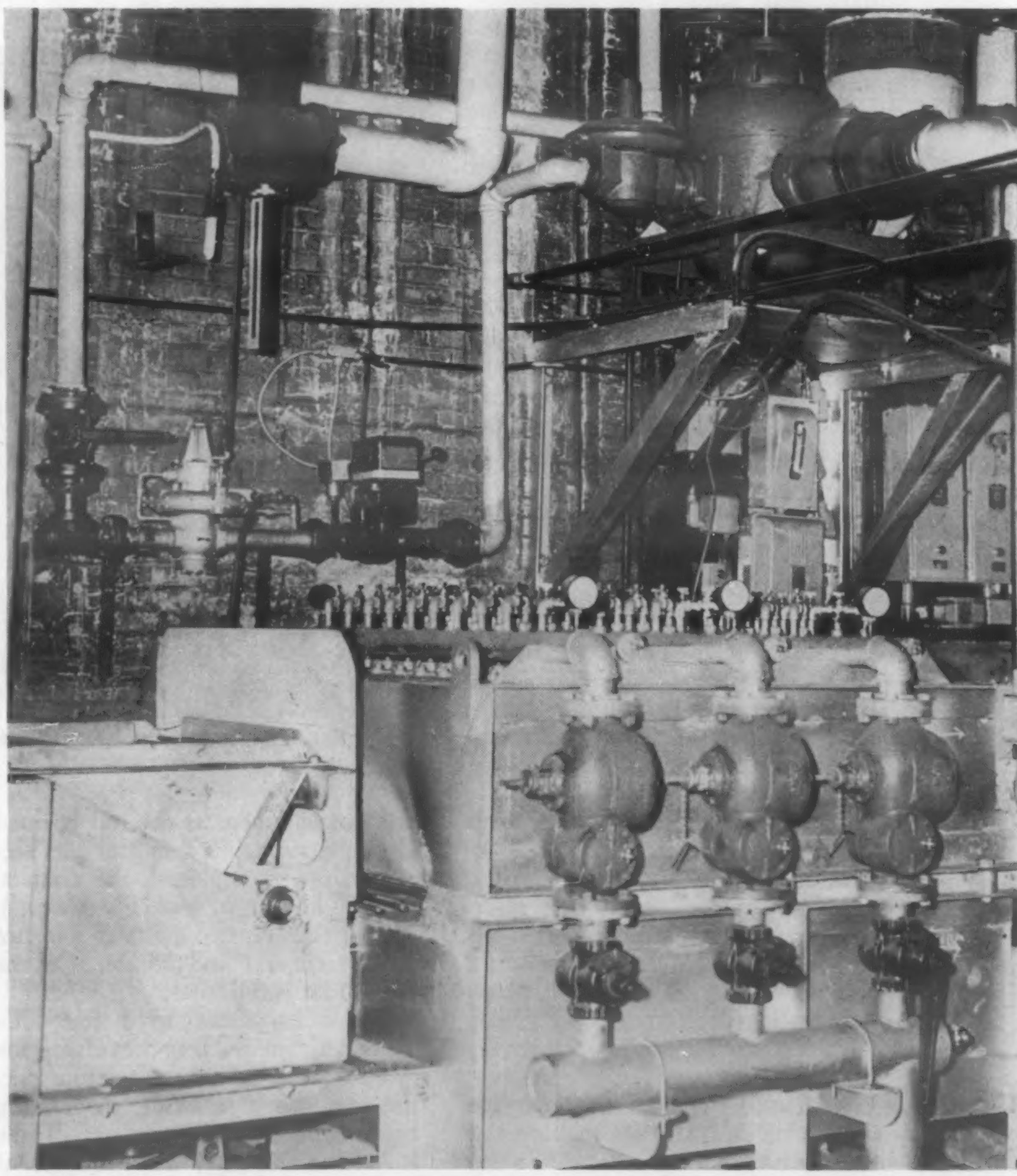
by S. B. VOORHEES, Works Metallurgist, Auburn Works, International Harvester Co.

• ONE OF THE VITAL steel assemblies in potato diggers is the link chain made of duplicate interlocking links. Each link is made from a 34-in. length of hot-rolled, C1085 high carbon steel bar, 7/16 in. in dia. The ends of the bar stock are formed into a difficult double U-shaped bend. These bends must be accurately made so that they are properly spaced and held to the desired radii. Also, the overall length of the links must be held to specifications. Since the annual production requirement is well over a million links, it was necessary to provide a set-up that would assure rapid production on a highly economical basis.

The method of production arrived at involves heating the bars in a radiant gas-fired furnace, then quickly forming the ends in a specially designed automatic hydraulic bending machine. After bending, the links are quenched immediately without reheating.

The hot bending machine was engineered and built by the International Harvester Co. In this machine, bends are made by precision dies, both ends of the bar being formed simultaneously. The automatic bender is supplied with bar stock heated to bending temperature, and produces at the rate of approximately 750 links per hr. Not only is the machine a time saver, but it insures accurate bending. In addition, the speed with which the bending operation is performed permits quenching without reheating immediately after bending.

Initially, the bar stock was heated in an old-type hopper fed tunnel



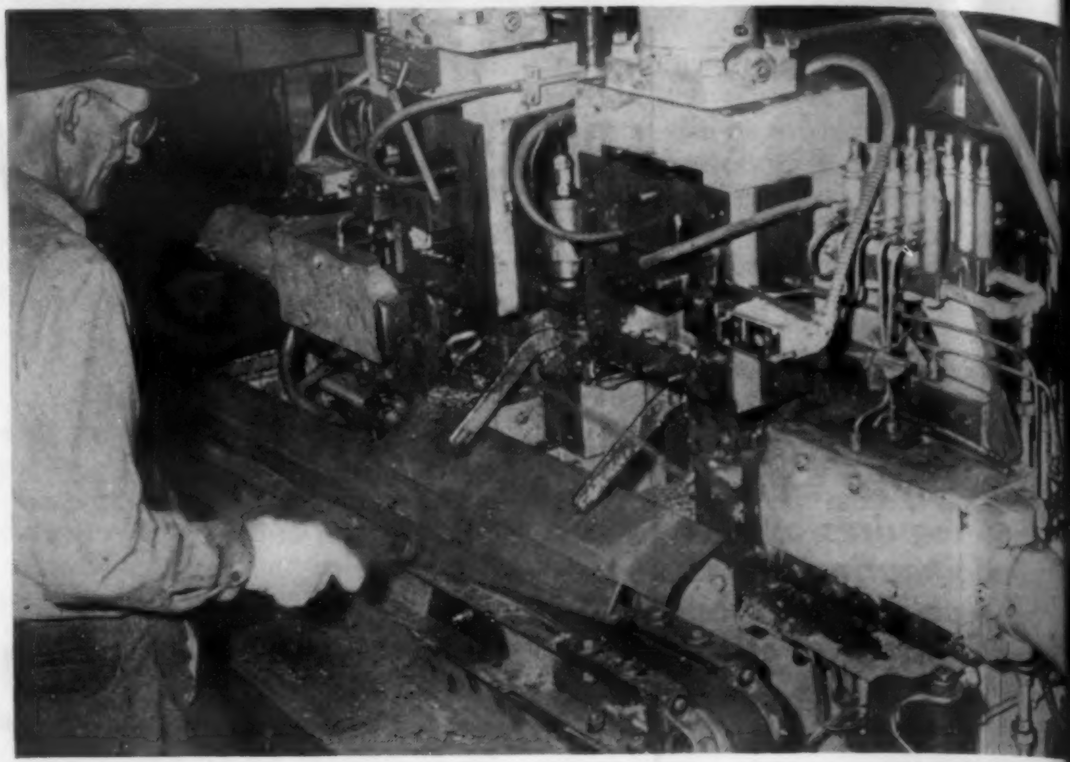
Bars are fed from the hopper at lower left onto this gas-fired radiant heating furnace at the rate of about 13 a min.

furnace provided with a continuous conveyor that advanced the rods to the bending machine in a 10-min. heating cycle. However, delays were encountered. The bars were not equally distributed on the conveyor by the hopper. Because of unequal spacing, the bars frequently shifted and became lodged in the furnace. Also, the length of the heating cycle itself was troublesome. These faults led to the installation of a new and much shorter furnace designed for radiant gas heating in a 2⅓-min. cycle, about one-fourth the heating time previously required. This furnace occupies a little more than a cubic yard of space and is supplied automatically from a hopper in which the bar stock is placed.

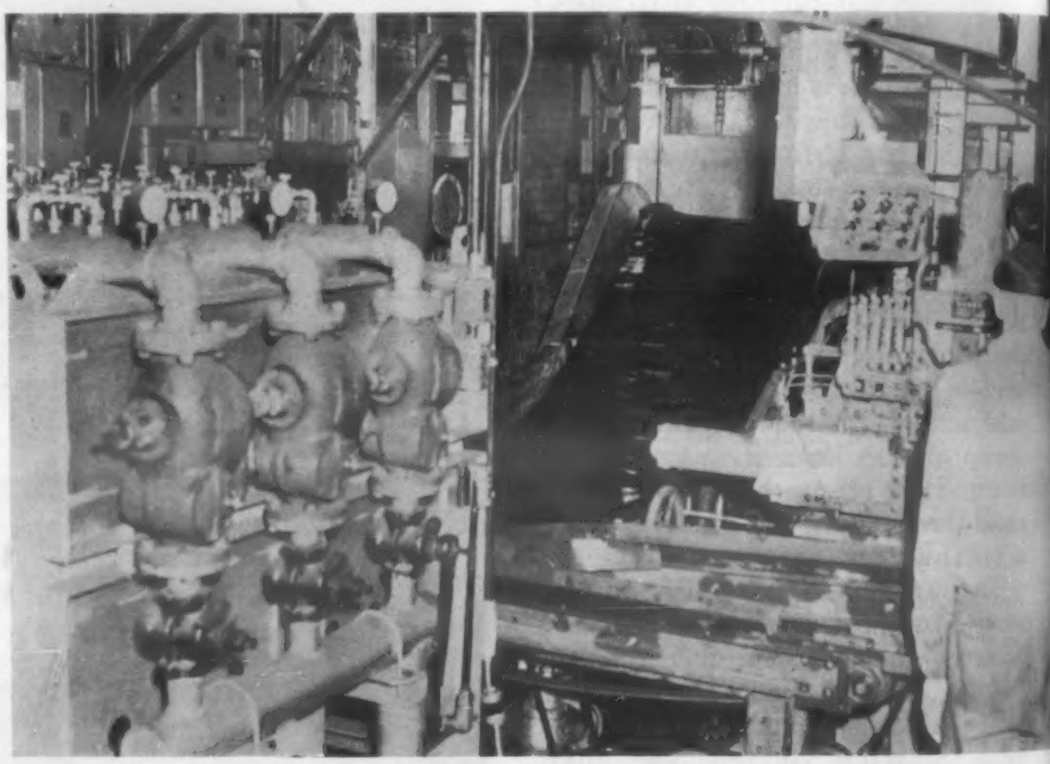
Natural gas of 1050 B.t.u. per cu. ft. heat content is supplied to the plant at a pressure of 25 psi. This pressure is reduced to an 8-in. W.C. before gas enters the furnace premixer and centrifugal compressor. The combustible mixture is fed through a safety valve to six manifolds, five of which are in regular use. Each manifold supplies nine burners.

The motor-driven sprocket that controls the feed from the hopper is set to space the rods 2 in. apart; the rods are advanced along the furnace hearth by silicon carbide toothed walking beams. In their travel through the furnace, the bars are subjected to radiant heat from above and below in gas that is completely burned as it passes through cup-like openings before entering the heating chamber. As this atmosphere is substantially neutral, there is little scaling.

A control, actuated by a thermocouple in the heating area, varies the gas supply in such a manner that rods drop from the end of the hearth at a uniform temperature of 1600 F. The time of travel through the furnace is 2 min. and 20 sec. This speed is set to supply one bar about every 4½ sec.



The special hydraulic machine having two sets of dies for making compound bends at each end of 750 bars per hr.



Looking between the radiant furnace and the bending machine toward the quench tank and the slat conveyor that carries links from the quench to the draw furnace in the background.

The bars leaving the furnace drop onto a belt conveyor and are quickly delivered to the special hydraulic bending machine. As the bars reach the operator, he picks each one up with tongs and places it in bending position. When the hot bar is properly positioned, it trips two Micro switches, placed in series, which activate the dies, and effect the successive bending operations. There are two sets of dies, one set making the bends at each end of the rod. As the rod is placed in the machine it contacts a gage at one end, closing the first switch; then, as the rod is lined up horizontally, it contacts the second switch, completing the contact. At the instant of switch activation, the bar rests on two dies a few inches from each end and adjacent to the two initial bends.

Bends are made in a four-slide operation: the holding dies clamp the rod in place, at the same time performing the first offset; descending bending dies bend each end of the bar down 90 deg.; the third set of dies, moving in from each side, offset the ends of the link to position the hooks for final forming, the bend is completed from below as dies move upward to form the final U. As the bend is completed, the holding die repeats—extending beyond its original position—and kicks the link off the die. The dies retreat, and the link slides down inclined supports onto a belt and is carried to the oil quench. By the time a formed link is ejected, another heated bar is delivered to the machine operator, who lifts it into bending position thereby starting the next cycle. Once the Micro switches are closed, the sequence of the cycle

Gaging a set of 15 links that are held in a fixture in interlocked position under spring tension. The end link at right must come in the gage slot for the group to pass inspection.

Links are assembled on this bench in sets of 97 or 107 to form the conveyor apron or chain.

is completely automatic.

Each of the successive parts of the cycle is controlled by a camshaft located at the rear side of the base of the machine. The cams actuate electrically controlled hydraulic valves directly above, and these valves, in turn, control the flow of fluid to and from the ram cylinders. Hydraulic fluid is supplied at 500 psi. from a pump in an adjacent room. When, as occasionally happens, the hydraulic machine must be shut down to adjust or change dies, the hopper feed to the furnace is also stopped and the few bars remaining on the short hearth are allowed to clear the furnace before the adjustment is made. This prevents overheating of stock.

Forming dies used in the bending machine are of hot work steel, heat treated. The wearing surfaces are overlayed with Stellite, welded on to increase wear resistance. Upper dies are water cooled, a feature that considerably increases die life.

Links after leaving the bending machine are quenched in a tank of approximately 500-gal. capacity. The oil is circulated for cooling to an 8,000-gal. storage tank with cooling tower attached to hold a temperature of 110 to 150 F. Links in the quench fall on a conveyor slatted to permit good drainage, and are fed to a draw furnace. Air in this furnace is recirculated to the top of the furnace and is mixed with hot air from the combustion chamber, which is heated to 1250 F maximum temperature. Temperature in the heating chamber is held at 800 to 900 F, the temperature which the links attain in their 17-min. travel along the 21-ft. steel conveyor hearth. On entering the draw, links have a hardness of 55 to 60 Rockwell C, but this is reduced, for better ductility, to 40 to 45 Rockwell C in the draw.

When the links leave the draw furnace, they are laid in racks to cool; after cooling, they are ready for assembly. As certain dimensions affected by the bending operations have to be held within moderately close limits to insure desired operation of the digger link aprons that the links form when assembled, it is necessary to provide the fixture and gage, shown in an accompanying photograph. A set of 15 links are placed in this fixture. Links are interlocked just as they are in the final assembly. When locked in the fixture under a predetermined tension, the straight portion near the end of the link, where the sprocket makes contact, must fit a slot in the gage. If the links fit the gage, the pitch from link to link, will be correct. If the gage does not fit, the bending dies, which are adjustable, must be reset to correct the error.

Although the potato digger apron is not of a high precision type and is subjected to heavy wear in service, only a moderate variation in pitch is permissible. Since the aprons are made of 97- or 107-link assemblies, a considerable cumulative error in overall length could result if individual links were slightly off dimensions. A cumulative error in length of over ½ in. is sufficient to warrant reworking.

Final factory length of the conveyor apron is established after links are assembled. At the same time, the apron is subjected to tension on both left and right sides; both sides are hooked to the assembly bench, while the opposite ends are attached to an air operated ram that applies the load. An initial stretch of 2 in. results. When released after stretching, the final length is rechecked, the apron is bundled, and except for painting, is ready for assembly on the potato digger.

Poke Welding Offers New Method of Joining Stainless, Aluminum and Mild Steel

Portability, simplicity of operation, high welding rate, and ability to use in otherwise inaccessible places makes inert gas-shielded arc spot welding applicable to difficult joining problems.

by F. J. PILIA, Development Engineer, The Linde Air Products Co.

• A NEW SPOT welding process making use of the inert gas-shielded arc principle has been developed to fill a conspicuous gap between resistance and fusion welding. The process, nicknamed "poke welding," is being successfully used to join such common metals as mild steel, stainless steel and aluminum, and should therefore find many applications in the metal industries.

With this process a spot weld is produced by heat from an electric arc between a tungsten electrode and one surface of two lapped pieces of metal. The weld differs from a resistance spot weld in that it is a result of fusion only, whereas a resistance spot weld is a result of high current and pressure applied to the electrodes. Welding action is controlled by current input to the arc and length of time the arc impinges on the surface of the material being welded. The tungsten electrode, the arc, and fluid puddle are all shielded with an inert gas in a manner similar to that used in conventional inert gas-shielded arc welding.

The equipment required for inert gas-shielded spot welding includes a standard 60-cycle a.c. metal arc welding transformer with built-in high frequency unit, a timing device, a welding tool, and a supply of inert gas. The timing device is similar to that used for resistance spot welding, except that longer time cycles are required for the arc, and instead of circuits for "squeeze" and "hold," there is a circuit for argon shutoff delay.

The tool for performing the weld consists of a gun of molded plastic about the size of a Colt "45" automatic. The tungsten electrode is located in the center of a water-cooled copper cup which bears against the workpiece. It is spaced back from the end of the cup approximately 3/32 in. This setting varies with the materials being welded and is adjustable from the working end of the cup.

Argon gas is distributed smoothly through the interior of the cup by a series of orifices in the electrode holding mechanism. Four "V" shaped notches at the base of the cup allow for purging the atmosphere of the

Close-up of the gun for making inert gas-shielded arc spot welds. Tungsten electrode is in the center of a water-cooled copper cup at the tip of the gun.

cup and for dispelling gases contaminated by welding. The cup is completely insulated from the current-carrying members of the gun.

Three hoses and one switch cord are encased in a rubber jacket approximately 25 ft. long to supply the welding current, cooling water, argon gas, and trigger control of the gun. This cable assembly is flexible and rugged, and capable of withstanding considerable abrasion and rough handling on shop floors.

To make a weld, the cup of the gun is pressed against the top surface of two overlapped pieces of metal. Enough pressure is applied to bring the surfaces into close contact where the spot is made. The trigger on the gun is depressed momentarily, closing the main contactor on the power supply to the welding transformer. As the primary contactor closes, the argon solenoid valve in the timing device is opened and argon gas flows to the cup of the gun. The high-frequency current, which is superimposed upon the welding circuit after the trigger has been depressed, ionizes a path between the electrode and the workpiece, initiating the 60-cycle welding current arc.

When welding current begins to flow, a preset timing cycle is initiated in either a mechanical clock or electronic timer. At the end of the correct time interval, the timer causes the primary contactor on the welding transformer to open and the arc is extinguished. A second timer continues the flow of argon to allow the electrode to cool in an argon atmosphere. The cooling time is usually 10 to 15 sec. for a 1/8-in. dia. tungsten electrode. The welding cycle cannot be repeated until the trigger has been released and the arc has been extinguished. This prevents unintentional refiring or time cycles longer than those which have been preset on the timer.

Materials

Thus far, inert gas-shielded spot welding has been used successfully in production on mild steel and stainless steel in thicknesses up to 0.078 in. Aluminum alloys of types 2S, 3S, 52S and 61S have also been welded with satisfactory results up to 0.064 in.

The process, although not recommended for some types of hot-rolled steel, such as SAE 1020, is satisfactory for such steels as SAE 1010, NAX, Yoloy, Cor-ten, Man-Ten, Armco iron, high-strength low-alloy steels, and alloy steels above SAE 1030. The welding of dissimilar thicknesses and different types of steel is also possible. For example, 0.040-in. sheet has been successfully welded to a 4-in. thick section in the various materials. Because of this, the process has been found practical for joining stainless steel liners to mild steel pressure vessels. In this type of work, the surface of the mild steel must be free from mill scale, rust or dirt, and the liner must contact the mild steel in the vicinity of the weld during the welding operation. Welds can be made on this type of construction in flat, vertical and overhead positions.

Welding conditions for aluminum are somewhat different from those of mild steel and stainless steel. Due to the high heat conductivity of aluminum, it is necessary that the sheets be in intimate contact, in order to obtain consistent and satisfactory results. To obtain the required fitup, some means must be employed to back the reverse side of the weld. In the case of large structures, this may be done by a bucking bar held by a helper. Where smaller objects are made on a production basis, blocks can be located in a fixture to back the weld. Surface conditions of aluminum materials also require special attention. Oxides, carbonaceous materials, and surface dirt must be entirely removed before welding. Chemical cleaning, vapor blasting or scratch brushing will produce satisfactory surfaces.

In the over-all picture the mechanical properties of inert-gas shielded spot welds approximate the generally accepted resistance spot-welding values. The accompanying table lists the properties of welds made on various thicknesses of mild steel and stainless steel by both the inert gas process and standard resistance welding.

Inert gas-shielded spot welds in stainless steel have the same corrosion resistance as inert gas-shielded continuous welds. When the types subject to carbide precipitation are welded to heavy mild steel sections as mentioned above, the zone of precipitation around the weld will be extremely narrow due to the quenching effect of the heavier mass behind the weld. Weld time and current cycles can be set up so that little dilution of the stainless steel liner by the mild steel back-up occurs. In fact, this dilution can be restricted to the area of juncture between the mild steel and stainless steel.

Fitup of the lapped surfaces must be good in order to obtain uniform results. Fitup should be at least such that the operator can apply sufficient body weight behind the welding gun to bring the sheets into contact.

Characteristics and Advantages

Perhaps the major advantage of gas-shielded spot welding is its ability to produce welds from one side of the joint only. Since no forging pressure is required to complete the weld, no backup or access to the other side of the weld is necessary. This characteristic makes it suitable to jobs where resistance spot welding machines cannot be used because of inaccessibility of one side of the joint. Metal-arc or oxyacetylene welding has been used in such locations, but inert gas-shielded arc spot welding is faster, easier, and requires less operator skill and training. By comparison, a single gas-shielded spot weld in 0.037-in. deep drawing mild steel has the same mechanical properties as a metal-arc weld 3/4 in. long or an oxyacetylene weld 1/2 in. long. The size and flexibility of the welding gun makes it particularly well suited for use on obstructed work.

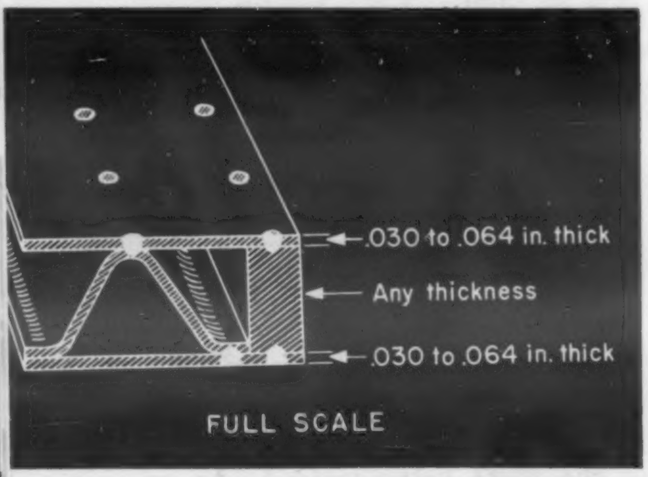
Another rather unique feature of the process is the fact that it is possible to control the current and time settings so that welds can be made without disturbance to the reverse of the sheet being welded. As an example of this, it was possible to produce five spot welds on an aluminum refrigerator vegetable bin assembly, in which the reverse side of the spots was exposed and painted with a high gloss enamel. When resistance spot welding was used for this operation, considerable finishing of the aluminum was required in order to remove all evidence of the spot welds. Inert gas-shielded arc spot welding was used without the necessity of this finishing operation.

Because the arc is primarily within the cup, only flash glasses or plastic face shields are required for protection of the operators. As this process produces no toxic fumes, smoke or spatter, welding booths and ventilating systems are not required. Also, due to the portability of the apparatus, extreme lightness, compactness and flexibility in relatively inaccessible spots, the number of spots produced per hour can be greater than that produced with the large and cumbersome special spot welding units required to reach such places.

Depending upon the material thickness, welding conditions and rapidity of operation, cost per spot ranges between 1 to 4 mils and welding times range around 1/2 to 6 sec. per spot. Weld rejects, due to weld

failures, average about 1½%. Malformed welds due to electrode contamination with the weld puddle and burn-throughs due to sheet separation and extremes in power factor variation average 4.2% rejects.

Inert gas-shielded arc spot welding has several inherent advantages which suit the process to production welding. The ability to join two pieces of metal in the lapped condition from one side of the sheet only has already been mentioned. The portability of the apparatus makes it possible to take the apparatus to the job conveniently rather than the job to the apparatus. Inert-gas spot welding equipment is considerably more portable than the conventional resistance spot welding guns. The gas-shielded gun weighs only 2 lb., and the cables and hoses necessary for its operation are encased within a hose sheath approximately 1-1/16 in. in dia. The welding cable in this assembly is only 10,000 circular mils in dia. The total assembly is about as light and flexible as a piece of 4/0 welding cable. This compares to the portable resistance spot welding guns that weigh upwards of 40 lb. and have two welding cables of several hundred thousand circular mils to carry the 5,000 to 10,000 amp. required to make a weld, as well as air, water and control wire. The length of cable on the inert-gas spot welding gun is 25 ft., as compared to a maximum of 8 ft. on a resistance welding gun.



This sketch shows a typical application of poke welding to corrugated sandwich type construction.

The fact that the process does not require skilled operators makes it possible to use it on conventional assembly lines without delay. The low power-demand by the welding transformer as compared to the power demand for resistance spot welding guns makes it extremely attractive for shops already overburdened with spot welding equipment. The portability of the gas-shielded gun and the fact that the welds are made from only one side of the sheet makes it possible to eliminate the cumbersome and costly special guns that would be required for resistance spot welding certain parts of the assemblies. This also makes it possible to use one gun on several or all of the welds within the reach of one operator and also helps to standardize on spare parts and equipment, resulting in a minimum of service time and ease of replacement problem.

Inert gas-shielded spot welding is not intended to replace resistance spot welding. The cost of the shielding gas and the long time cycles required with the inert-gas shielded process make it impossible to compete with resistance spot welding in those applications where conditions favor the latter. It is expected that the new inert gas-shielded spot welding process will find its greatest applications where its characteristics such as freedom from back-up, unskilled operation, low power demand, and portability will give it an advantage.

Applications

One of the first uses of inert gas-shielded arc spot welding was for automobile body construction. The automobile body is designed primarily around the resistance spot welding process, with metal arc welding being used where resistance spot welding is not feasible due to the size of the machine required, the obstruction of the work, or inability to reach the opposite side of the work for resistance welding backup. The inert gas-shielded arc spot welding process answers many of the problems on body construction which until now have been solved by using metal arc welding. The process is particularly advantageous in the framing jig because the equipment is extremely portable, the spot welds are dependable, and the gun can be used by nonskilled labor.

Another application which is particularly suited for the process is the production of spots which are subsequently covered with body solder. Previously, with metal arc welding on this type of joint design, it has been necessary to grind the metal arc weld flush or below the intended surface of the solder fill. With gas-shielded arc spot welding, the grinding operation is eliminated. The welds produced are relatively flat and require no further preparation prior to filling with solder.

A number of the accompanying illustrations show the application of the process to automobile body fabrication at the Briggs Manufacturing Co. One application in this plant involves attaching cross-bracing for the rear seat in a two-door body. The cross-bracing was previously attached by metal arc welding. In another case the front door post assembly is joined to the floor pan in the framing jig. These welds were previously made by metal arc. While the joint design is ideal for resistance welding, it was not considered practical because of the size of the unit required to reach around the sections of the body to be welded.

The method is used in welding of the front assembly consisting of the fire wall and windshield frame for a convertible type car. This is a typical example of welds that would be diffi-

Mechanical Properties of Inert Gas-Shielded Spot Welds

	Inert Gas-Shielded Spot Weld				Resistance Spot Weld			
Material and Gage	Ten. Shear, Static, Lb. to Failure	Dir. Ten., Static, Lb. to Failure	Ten. Shear, Impact, Ft.-Lb.	Dir. Ten., Impact, Ft.-Lb.	Ten. Shear, Static, Lb. to Failure	Dir. Ten., Static, Lb. to Failure	Ten. Shear, Impact, Ft.-Lb.	Dir. Ten., Impact, Ft.-Lb.
Carbon Steel								
0.032	1115	290	42.5	5.8	700	575	34	10
0.045	1320	566	61.2	9.2	1250	1600	90	25
0.057	2150	1083	83.2	43.0	1800	1560	150	40
0.094	3318	1850	117.2	44.2	3800	2300	220	100
Stainless Steel								
0.020	1236	580	33.2	12.1	600	500	3.3	2.0
0.060	5018	1986	154.0	49.1	3400	2900	39.0	34.0

cult to back-up for resistance welding due to obstruction by structural sections behind the weld.

Body brackets are also welded to the floor pan by this process. The bracket is made of 0.064-in. material, and in this particular operation the weld is being made on the edge of the bracket, the cup being placed half-way over the edge of the bracket. This produces a weld similar to a gas-weld tack.

In welding the side panel assembly to the floor pan, two gas-shielded spot welds are usually made on this flange in the fixture, and the balance of the welds are made after the body is removed from the fixture and is proceeding down the line. A few carefully selected spots properly located during body framing eliminate much of the poor fitup usually encountered on the line. This particular flange without the welds would open approximately 3/16 to 1/4 in. upon being removed from the framing jig. Two welds on each flange completely eliminate this separation.

In some cases inert gas-shielded spot welds replace metal arc tack welds, such as on the front assembly. These welds are subsequently covered with body solder and so must be flush or slightly lower than the surrounding surface. When metal arc welding was used, the welds required grinding to remove the excess weld metal. With gas-shielded spot welding, no grinding is necessary.

In joining the side panels to the front assembly while in the framing jig, resistance welding could not be used because of inaccessibility to the reverse side of the weld. Due to the extremely different section thicknesses—0.037 to 0.090 in.—gas welding was too slow to keep up with the fixture. The metal arc could not be used on the framing fixtures because of flash, smoke and spatter. These welds on each side of the body are ideal for inert gas-shielded arc spot welding, and are responsible for approximately 70% reduction in door fitting time on the line. The welds prevent the distortion of the door frame when the body is lifted from the framing jig.

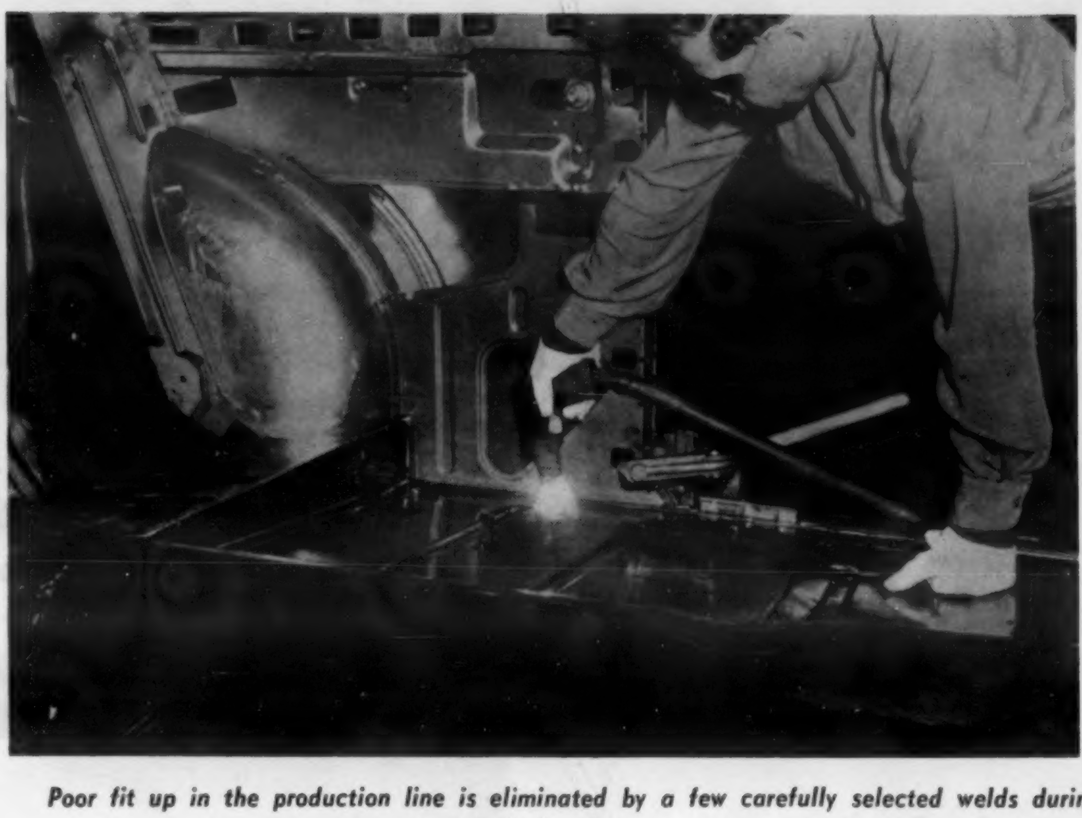
Besides the specific cases just cited, inert gas-shielded spot welding is also used to weld interior structural members to the door frame, to attach the front seat brackets to the floor pan, and to reinforce resistance welds along the door sill joint.

In other types of body construction poke-welding is useful. The process can be used satisfactorily to attach the top sheet to a corrugated sandwich, such as is used in the manufacture of trailers and railway equipment. A corrugated sandwich is made by resistance welding the tops of the corrugated sheet to one of the side sheets. When attaching the final sheet to the sandwich, difficulty due to the inaccessibility of the reverse side of the corrugation makes resistance welding impractical for the final operation. Gas-shielded arc spot welding has been used on these operations with satisfactory results. Sandwiches have been made employing as many as 700 welds in this manner for the final assembly.

Due to the portability, visibility and the little skill required, this tool becomes extremely useful for railway car and automotive trailer repair service especially for stainless steel bodies and parts. Although many of these structures were originally fabricated with resistance welding, when repairs are necessary, resistance welding is usually impractical, due to the specialized units that would be required for the individual repair. In many cases, resistance welding cannot be used at all because the reverse side of the section to be welded cannot be reached for back-up. For such repairs, it is merely necessary to install a patch or repair from the outside of the structure and use gas-shielded spot welding for the final joint.

Metal furniture and cabinets can be easily fabricated by this process because the equipment is so portable and the gun can be used in very limited spaces. Manufacturers of such widely diversified objects as outdoor display signs, home appliances, and food handling equipment will find wide use for the process.

From the above examples it is evident that inert gas-shielded arc spot welding is a useful and versatile new joining process. It should develop into as important a process as the resistance welding process, metal arc welding process, oxyacetylene welding process, and the various other generally accepted welding processes for the metal-working industry.



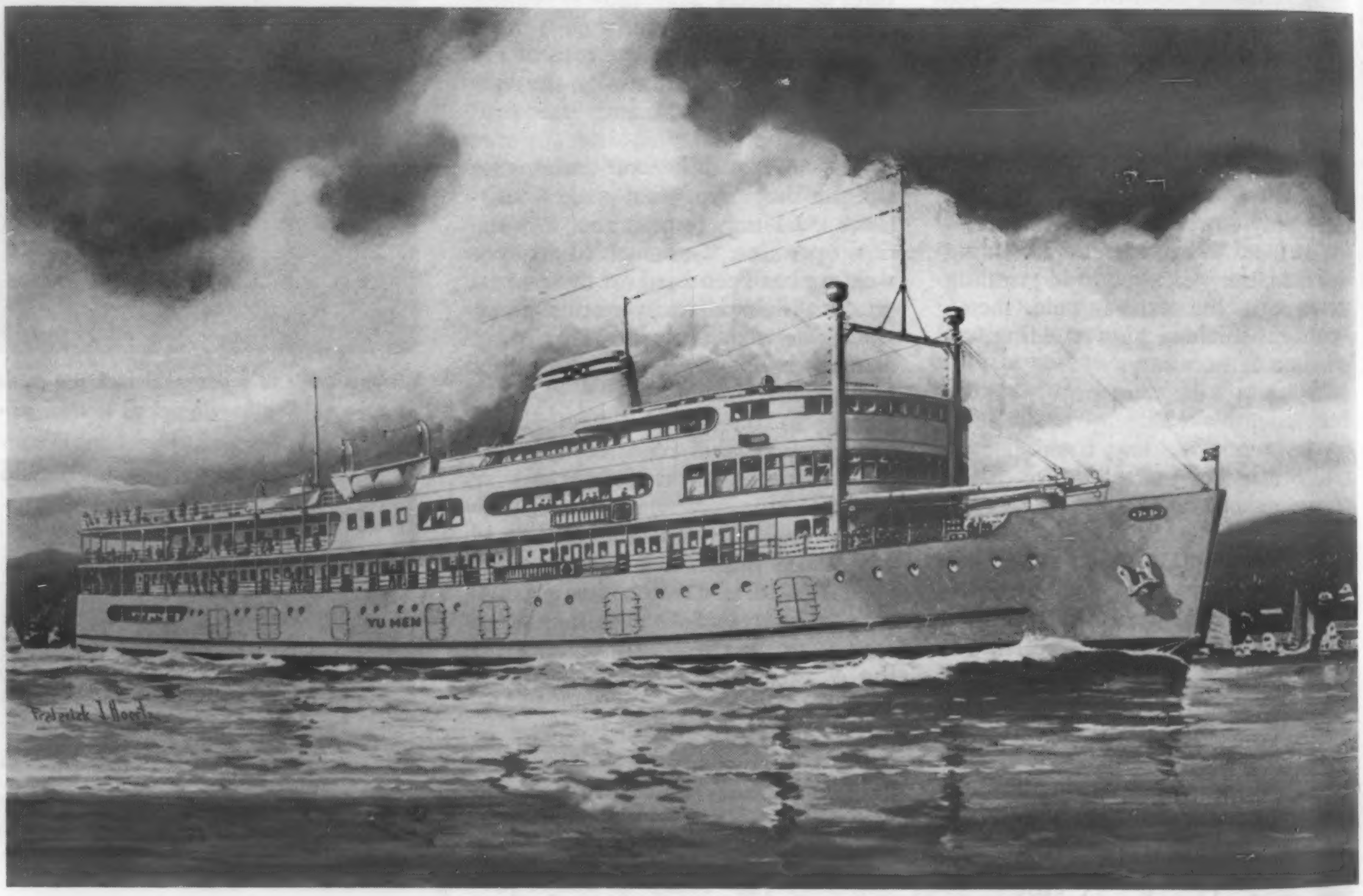
Poor fit up in the production line is eliminated by a few carefully selected welds during body framing.

Welds similar to a gas-weld tack are made by poke welding body brackets to floor pan.

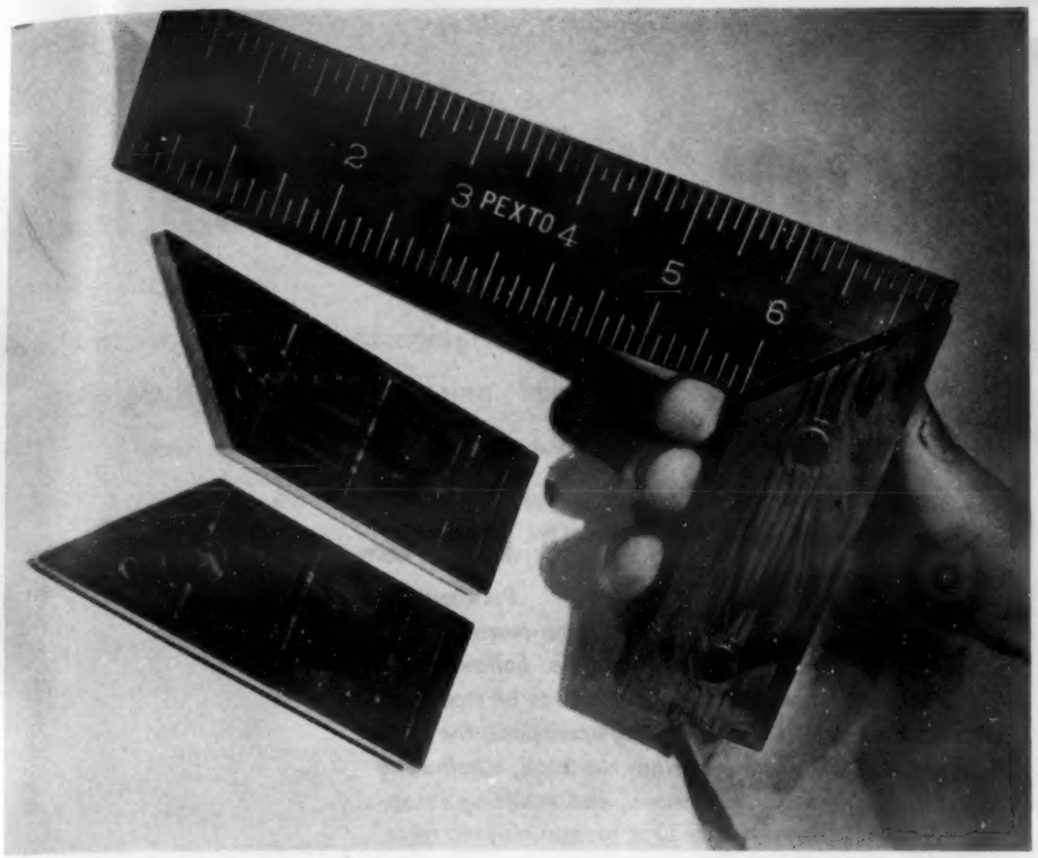
Welds by gas-shielded spot welding on the windshield. They will be covered with body solder, and no subsequent grinding is necessary.

Materials at Work

Here is materials engineering in action . . .
New materials in their intended uses . . .
Older, basic materials in new applications . . .

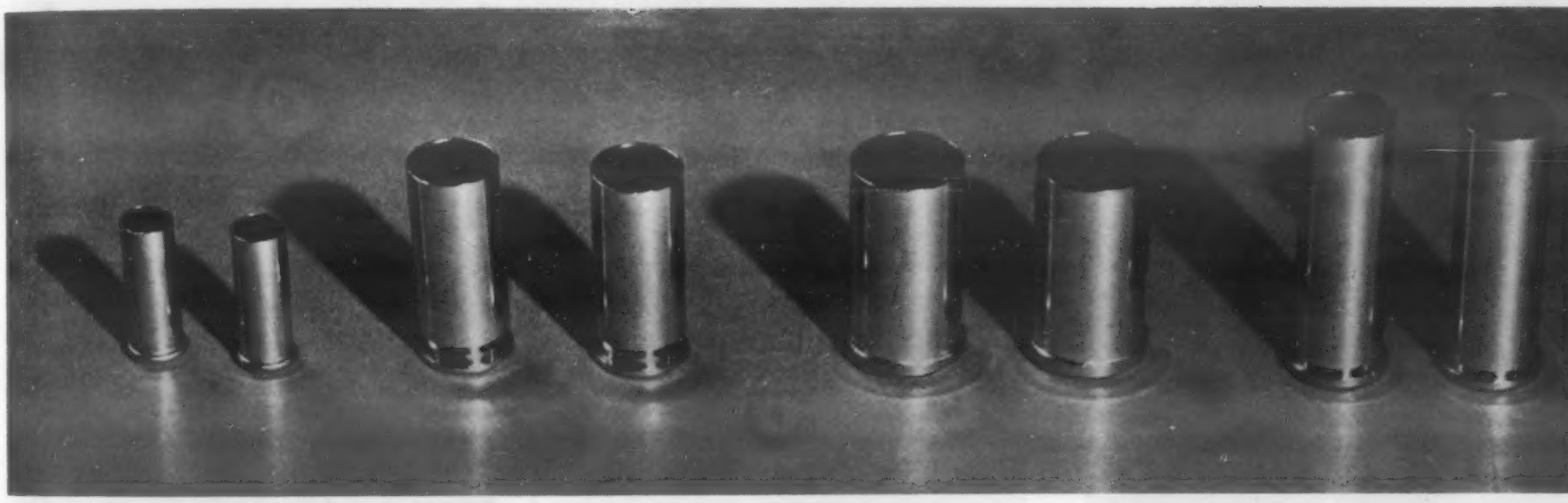


ALUMINUM ALLOY SUPERSTRUCTURE ***Designed and built for Yangtze River service, this 283-ft. combination passenger and freight vessel of the Ming Sung Industrial Co. makes widespread use of aluminum alloy to reduce weight and subsequent vessel draft. The entire superstructure, including deckhouse sides and framing, decks and deck beams, joiner bulkheads, doors, furniture, ladders, rails, stanchions, hatch covers, cargo ports, stack, ventilation ducts, window frames, lifeboats and davits are all of this lightweight alloy. Cor-Ten, a high-tensile corrosion and abrasion resisting steel manufactured by the United States Steel Corp. is used for the hull structure. This material results in a 7% weight saving over conventional steelplate. The extra cost of this higher grade steel is felt to be more than offset by the increased payload that results. The vessel was designed by Philip L. Rhodes, New York, and built by G. T. Davie & Sons, Quebec. Photo courtesy United States Steel Export Co.***



ETHYL CELLULOSE TRY-SQUARE HANDLES

Injection-molded of ethyl cellulose, the colorful and long-wearing handles of this try-square are light in weight and tougher than the hardwoods conventionally used. The plastic handles, a product of Peck, Stowe & Wilcox, Southington, Conn., are molded in two precision-fitting sections, require a minimum of finishing, and are ideally adapted to rivet-assembly. They have excellent dimensional stability over a wide temperature range and will not chip, crack, or peel. Available in a variety of colors in attractive grain or mottled finish. Photo courtesy Hercules Powder Co.



NICKEL-PLATED AMMUNITION

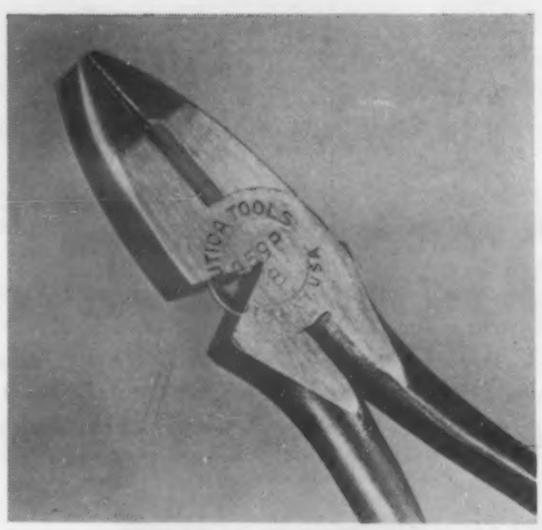
To improve corrosion resistance and add sales appeal, Remington Arms Co., Inc., Bridgeport, Conn., nickel-plates the brass cases of its .22-cal. rimfire and its .32-, .38-, .45- and .357-cal. centerfire cartridges. The cases are given this bright and durable surface in a six-station barrel unit. A double-salt-type plating solution is used with an organic brightener added to give the product the desired luster. To meet requirements, the electrodeposited nickel surface must be lustrous, non-peeling, and ductile. After plating, the parts are rotated, drained, and rinsed. A final washing with a burnishing compound provides a finish that facilitates feeding through subsequent machine operations.

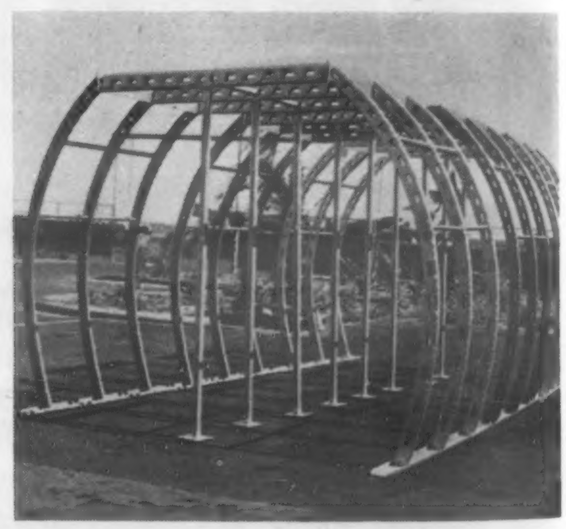
CELLULOSE ACETATE BUTYRATE LENSES

Shatterproof, weather-resistant tail-light and signal-light lenses are molded of either red or amber transparent Tenite by J. H. Shepherd Son & Co., for the Bowman Safety Service. The largest lens measures 6½ in. in dia. and has decalcomania lettering on the underside which stands out sharply when the light flashes on behind it. This lens is intended for ambulances, fire trucks, police cars and signal lights. The molded Tenite has high impact resistance and is tough and resilient under heavy blows. A special formula, incorporating ultraviolet-ray inhibitors to increase the resistance to fading, is used for the plastic.

STEEL GRIT AND PLASTIC HAMMER HEAD

Between the Tenite faces of this non-marring, non-recoiling hammer is a hollow metal head containing a charge of steel grit. During hammering operations, the steel grit slides within the head, eliminating recoil and shock, and resulting in approximately 30% greater striking force. The hammer faces, injection-molded of cellulose acetate butyrate, withstand heavy impact without cracking or flaking and are force-fitted directly onto the grooved nipples of the hammer head. The hammer is manufactured by Drake Industries, Ltd.





RUBBER-LINED ACID STORAGE TANK

Believed to be the largest tank of its kind in the world, this 2,000,000-gal. capacity unit will be used, when completed, for the storage of weak sulfuric acid. The flat-bottomed tank is lined throughout with 30 tons of 3/16-in. rubber by B. F. Goodrich Co., and measures 100 ft. in dia. The side wall of the tank is 30 ft. high and the domed top rises to 45 ft. at its highest point.

POWDERED IRON LUBRICATING RING

To assure proper joint lubrication, The Utica Drop Forge & Tool Corp. utilizes a ring of compressed powdered iron between the riveted halves of the pliers manufactured by their firm. This lubricating ring, having about 30% porosity and saturated with oil, floats in a channel that is cut around the rivet hole of each plier half. After assembly, the oil works out of the ring and into the joint as the pliers are used, resulting in a longer wearing joint and less frequent re-oiling.

MAGNESIUM DRESS RACKS

Designed to fit large cargo planes, these magnesium racks are used by American Airlines, Inc. for the transcontinental shipping of women's dresses. The racks weigh only a few hundred pounds, but are capable of holding 10,000 dresses. The garments are shipped unpacked on hangers and arrive at destination without the mussing and wrinkling normally encountered in wrapped delivery.

Materials & Methods Manual

47

This is another in a series of comprehensive articles on engineering materials and their processing. Each is complete in itself. These special sections provide the reader with useful data on characteristics of materials or fabricated parts and on their processing and application

Forgings—
Ferrous and Nonferrous

by N. Bruce Bagger, Associate Editor, Materials & Methods

There is an almost unlimited variety of ferrous and nonferrous metals and alloys that can be forged successfully. But there is almost an equally unlimited variation in the ease with which this can be done. The key to forgeability lies in the composition of the materials, the properties desired in the finished forging, and the uses to which it will be put. Seven basic categories of forgeable metals are discussed, not from the standpoint of the actual forging techniques involved, but from the relative behavior they, and the specific materials they comprise, exhibit for forgings applications.

Contents

Introduction

Forging is perhaps the oldest metal working method known. In the early dawn of civilization mankind stumbled on the fact that a piece of heated metal, when subjected to repeated blows, acquires a degree of toughness and strength far surpassing that of the original piece. This phenomenon, long unexplained, was utilized in the manufacture of metal articles as man developed through the centuries. As early as 5500 B. C., Egyptians during the reign of Menes I forged copper and its alloys into implements of war and peace. Later, the Etruscans, who settled on what is now the western shores of Italy, forged bronze into chariot plates, horses' bits, and other instruments of daily life. Still later, the smiths of Damascus and Toledo produced steel sword blades which, although now at rest in the museums of the world, are recognized even by today's standards as prime examples of forging art. In America, the history of forgings dates from Indian civilization in the Great Lakes region where copper was forged for hunting and war equipment. The first white settlers, with their charcoal fires and deerskin bellows, forged farm tools and hardware from the iron anchors and fittings of the ships that brought them to the New World.

Thus, increasing knowledge, gradually acquired, was passed on and added to by each succeeding generation. But it was only with the advent of modern laboratory techniques that a full understanding of forging quality was obtained and steps taken to assure this quality through the use of materials specifically suited for particular forging applications.

It is now known, of course, that the blows of the forging hammer consolidate the metal structure and produce a definite grain flow in the material being forged. The resultant forging has the greatest strength, toughness and fatigue resistance that is possible for the metal to acquire. Forgings, because of their increased tensional and torsional strength, permit a part to be made with considerable reduction in bulk and weight. Close tolerances can often be held to reduce machine labor and tool costs.

Forgings commonly fall into four major categories or types: (1) flat or open die; (2) drop; (3) upset; and (4) press. Flat die forgings are usually considered to be the oldest type. In this process, billets of heated metal are hammered into shape on an anvil the same way as a blacksmith fashions a horseshoe, but high-powered steam hammers furnish the "muscle."

Drop forging is the process of shaping pieces of heated metal between two closed-impression dies; one affixed to the hammer, the other to the anvil. These die impressions or cavities conform in size and shape to the size and shape of the finished article, with proper allowance made for subsequent shrinkage as the forging cools. The regulated and intermittent impact of the hammer on the heated metal forces it into every part of the mating dies. This tends to "knead" the metal into a dense, tough and fibrous structure. Any forging metal in excess of that needed to fill the die cavity is squeezed out between the dies to form a thin protrusion, called a flash, which must be removed later by trimming. With flat or open dies, no flash is formed. Closer tolerances can be held in drop forging than in the flat die type, and for high production work, drop forging is usually used because the economies of speed and greater accuracy offset the additional cost of special dies.

Upset forging is a process of hot deformation in which dies are axially brought to bear with tremendous pressure on heated bar stock. Production by this method is rapid and holes can be readily pierced in the parts during the forging process. Close tolerances can be held and machining of finished forgings is often eliminated. Certain design, production and assembly costs can often be reduced or eliminated, since parts of complex shape can be upset forged as an integral unit instead of being made in two or more pieces.

Press forging is a variation of the drop forging process, the difference being that the deformed material is squeezed into the die cavities with a single, sustained blow, whereas in drop forging repeated blows are used.

Thus forging, as a manufacturing process, provides several distinct advantages that cannot be duplicated by other methods of working metal. Among these advantages are: (1) Strength: high tensile and impact strength are obtained through controlled direction and concentration of grain structure and fibrous flow lines. (2) Combination of physical properties: correctly proportioned combination of physical properties essential to meet a specific service condition. (3) Reduction of dead weight: maximum strength and toughness in lighter sectional thickness. (4) Reduction in cost: particularly at point of assembly because forgings quite often require less time to machine and finish. Cost reductions are also obtained because of fewer rejects since forgings are unusually free of concealed defects. (5) Assembly of complex parts: rapid assembly by welding, because forgings provide welding adaptability of widest range. (6) Greater safety: continued dependable performance throughout long service life and a reduction of accidents to men and machines. (7) Maximum metal quality: controlled flow line structure of metals is obtained at points of greatest shock and stress.

There are, however, certain limitations imposed on forging as a manufacturing process. Die costs, for instance, are usually more expensive than patterns for casting operations. And certain shapes cannot always be forged because of intricacies in their design; whereas these same shapes might be readily manufactured by either casting or some other production technique. Again, where a specific part or item is required to be made of a certain material, it may not always be feasible to use a forging operation because of difficulties encountered in forging the material in question. Some forgings may require considerable heat treating, machining and finishing before a satisfactory product is achieved. But although this depends upon the part and the material from which it is forged, it must nonetheless be considered when making materials selections and evaluating production techniques.

Although not necessarily classed as a disadvantage, certain criteria peculiar to forging design must also be considered when evaluating forgings from both a materials and process standpoint. These design factors have a great effect on the economy and practicability with which particular materials are forged for specific applications. In all drop forging design, it is necessary to allow a taper or "draft" on all surfaces parallel to the direction of the motion of the ram. This prevents the forging from sticking in the die. This draft is usually held to an angle of 7 deg. in hammer forging on external surfaces and 10 deg. on internal surfaces, but these angles can be varied with different materials and parts. A 1-deg. minimum is usually held in upset forging. Parting lines are usually placed at the center of the forging and kept in as nearly one plane as possible to minimize draft and facilitate forging. Since sharp radii and fillets increase the difficulty of filling die impressions and tend to promote fatigue cracks, good design prohibits their use. Pockets and recesses are usually kept to a minimum, since they result in increased wear on dies. Ribs should be kept low and wide because the forging material will cool more rapidly and lose plasticity in thin die crevices.

From all this, it is apparent that a knowledge of the characteristics of forgings and the metals from which they are made is essential in order that they can be evaluated and compared with other materials and other manufacturing methods. A comparison such as this will determine what advantages, if any, are to be obtained by using forgings instead of alternate production methods for specific product applications of various metals.

There is an almost unlimited variety of ferrous and nonferrous metals and alloys that can be forged successfully. But there is almost an equally unlimited variation in the ease with which this can be done. Composition of the forging stock and the behavior of such composition when subjected to mechanical working and heat treatment cause these widespread differences. As a general rule, the alloying constituents determine the relative forging ease, *i.e.* increasing the alloying constituents increases the forging difficulty and wear on dies. Of the many forging metals available, each has certain definite attributes of strength, wear, fatigue, durability, etc., that suit it for specific applications. But, as is often the case, when these various forging metals are classified or grouped, some overlapping occurs, as a certain specific material may quite logically fall in more than one of the general, over-all categories. However, forgings are usually classified according to the following general groups: (1) carbon steels; (2) alloys steels; (3) corrosion resistant, heat resistant and stainless steels; (4) iron; (5) copper, brasses and bronzes; (6) nickel and nickel-copper alloys; and (7) light alloys.

Each of these groups is subdivided and discussed, not so much from the actual forging technique involved, but rather from the standpoint of its relative behavior as a forging material.

Carbon Steels

Straight carbon steels are perhaps the most widely used forging materials for general purpose applications. Carbon steel forgings, when properly applied to the conditions for which they are designed, are economical and have good properties within the limits of steel's basic characteristics.

The straight carbon steels are usually considered to comprise three general groups: (1) low-carbon, (2) medium-carbon, and (3) high-carbon. Generally speaking, the addition of slight amounts of sulfur to low- and medium-carbon grades provides better machinability in these steels but simultaneously reduces their maximum strength. But too much sulfur affects the forgeability of regular carbon steels to the extent that cracks are more likely to develop during forging operations. Additions of manganese to these steels improve machinability without any sacrifice in strength. A listing of some typical carbon steels suitable for forgings is shown in Table I.

Low-Carbon Steel

Steels in this category have a carbon content up to about 0.28% and are used for forgings subjected to moderate conditions where hardenability and fine machinability are not required. They are also widely used for carburized parts where resistance to abrasion is important. The steels forge readily and are easy to machine but do not respond too well to hardening and tempering operations.

Medium-Carbon Steel

With a carbon content between 0.30 and 0.55%, steels in this group can be successfully heat treated so that desired characteristics of hardness, toughness, wear and impact resistance can be achieved to a greater extent than is possible in the low-carbon group. Forgings are best made of medium-carbon steel when the carbon content does not exceed 0.35%. Steels in the medium-carbon range do not harden readily to hardnesses beyond machinability. Hence, they are not used where high hardness is required.

High-Carbon Steel

Steels in this grouping have a carbon content above 0.50% and are used for applications requiring greater hardness, toughness, abrasion resistance and wear resistance. These steels forge and machine well, but proper heat treatment is essential for satisfactory results. The higher carbon content is advantageous in forging large parts or those with heavy cross-sections. But in sections of large area, the ultimate hardness does not penetrate to a great depth and center hardness is much less than that obtained on the surface. As the carbon content approaches the range limit, heat treatment results in hardness beyond the machinable range.

Alloy Steels

These steels are alloys of carbon steel with one or more elements added to achieve certain desired properties that are not available in the straight carbon series. Forgings from these steels are used wherever higher strength, greater toughness, higher hardness, better wearing qualities, resistance, durability, etc., are required. The proper selection of an alloy steel of a particular analysis is usually dependent upon the particular service conditions to which the part in question is to be exposed.

In general, alloy steel forgings are subjected to some form of heat treatment: hardening by quenching and subsequent reduction of stress or hardness by tempering. This is done on the principle that maximum economy in the use of alloying elements requires the highest possible strength consistent with other needed qualities. To accomplish this, multiple heat treatments and a complex sequence of manufacturing operations are often the most economical practice. In all cases, however, a certain balance between ultimate properties and ease of fabrication must be maintained for over-all production economy, since as alloy steels increase in strength and toughness they tend to become increasingly difficult to forge and machine, and increase wear on forging dies.

The major alloy steels comprise the following groups: (1) nickel steels, (2) nickel-chromium steels, (3) molybdenum steels, (4) chromium steels, (5) chromium-vanadium steels, and (6) silicon-manganese steels. A listing of some typical alloy steels in each of these categories is shown in Table II.

Nickel Steels

Nickel is the first alloying element added to improve the mechanical properties of straight carbon steel. The result, nickel steel, has greatly improved resistance to impact, shock and fatigue, and its tensile strength is increased without a corresponding reduction in ductility or toughness. Nickel steel has low grain growth at forging temperatures and, because of the high nickel content, requires lower heat treating temperatures which reduces warping and scaling. Nickel steels have good corrosion resistance, forge and machine readily, and are used where greater toughness than that obtainable in the straight-carbon series is required.

Nickel-Chromium Steels

The nickel-chromium steels are characterized by increased tensile strength and improved hardenability. The combination of the nickel with the chromium as an alloying element in the steel offsets the somewhat deleterious tendency the chromium has to increase the heat treating temperatures required. Steels in this group have exceptional corrosion resistance and forge and machine reasonably well. They are used primarily where economy and strength are major product factors.

Molybdenum Steels

The steels in this category have increased tensile strength and reduced grain growth at elevated temperatures. The presence of the molybdenum permits ready machining and increases hardness penetration. Molybdenum steels can be forged and heat treated over a wide temperature range and are used for many carburizing applications.

Chromium Steels

The chromium steels have improved tensile strengths and exceptional deep hardening characteristics, as well as good creep resistance at elevated temperatures. They forge and machine moderately well, but are most universally known for their hardenability. Used principally for applications requiring high strength and toughness.

Chromium-Vanadium Steel

The steels in this category are characterized by exceptional strength and anti-shock and fatigue properties. They have fairly low grain growth at the temperatures required for forging and heat treating operations, and are used primarily for parts subjected to extremely severe service conditions. The addition of vanadium has a tendency to enhance the beneficial effects of the chromium in the composition.

Silicon-Manganese Steel

The silicon-manganese steels, like the chromium-vanadium group, are best noted for their extremely high strength and fatigue-resistant properties. The addition of silicon increases the hardenability and improves the oxidation resistance while the manganese offsets any tendency toward brittleness in the steel. The steels in this group are used principally for parts subjected to extreme service conditions. Forging is somewhat difficult.

Small magnesium press forging immediately after forging operation. Trimming die can be seen in front of operator. Note gas-heating equipment around lower forging die. (Courtesy of Dow Chemical Co.)

Table I—Typical Carbon Steels for Forgings

Designation	AISI Type No.	C	Mn	P	S	Others	Tensile Strength, Psi.	Yield Strength, Psi.	Machinability	Forgeability	Normalizing Temp., deg. F	Annealing Temp., deg. F	Quenching Temp., deg. F	Maximum Forging Temp., deg. F	Characteristics and Applications
	Composition						Physical and Mechanical Properties				Heat Treatment				
Low Carbon Steels	C 1010	0.08 to 0.13	0.30 to 0.50	0.04	0.05	—	51,000	29,000	Excellent	Excellent	1650 to 1750	1000 to 1350	Water quench 1650 to 1700	2400	Compositions quite soft; used where maximum ductility is desired. These grades are used for most carburizing. Uses: camshafts, wristpins, etc.
	C 1015	0.13 to 0.18	0.30 to 0.50	0.04	0.05	—	67,000	45,000	Excellent	Excellent	1650 to 1750	1000 to 1350	Water quench 1650 to 1700	2400	
	C 1020	0.18 to 0.23	0.30 to 0.50	0.04	0.05	—	67,000	45,000	Not recommended where fine machining is required	Excellent	1650 to 1750	1000 to 1350	Water quench 1600 to 1675	2375	For general forgings where economical steel plus good physical characteristics are needed without requiring heat treating. Uses: manhole covers, brackets, flanges, etc.
Medium Carbon Steels	C 1030	0.28 to 0.34	0.60 to 0.90	0.04	0.05	—	75,000	46,000	Excellent	Good	1600 to 1657	1250 to 1375	Water quench 1575 to 1650	2350	For general forgings where good response to heat treating is desired in an economical steel. Not used for carburizing. Uses: frames, hooks, shackles, yokes, etc.
	C 1035	0.32 to 0.38	0.60 to 0.90	0.04	0.05	—	92,000	55,000	Good	Good	1575 to 1650	1575 to 1650	Water or oil quench 1525 to 1600	2350	Suitable for small and medium size forgings where moderate physical properties are desired. Caution needed in quenching small sections. Uses: wheel flanges, steering arms, etc.
	C 1040	0.37 to 0.44	0.60 to 0.90	0.04	0.05	—	93,000	58,000	Good	Fair	1575 to 1650	1550 to 1625	Water or oil quench 1500 to 1575	2350	Suitable for small and medium size forgings where deep hardening characteristics are desired. Caution needed in quenching small sections. Uses: tubing, crankshafts, connecting rods, etc.
	C 1045	0.43 to 0.50	0.60 to 0.90	0.04	0.05	—	96,000	62,000	Good	Fair	1550 to 1650	1525 to 1600	Water or oil quench 1475 to 1550	2300 to 2350	Suitable for large size forgings but extreme caution needed when water quenching small diameters or thin sections. Uses: spline shafts, large crankshafts, large connecting rods, etc.
	C 1050	0.48 to 0.55	0.60 to 0.90	0.04	0.05	—	97,000	63,000	Good	Fair	1550 to 1650	1525 to 1600	Water or oil quench 1475 to 1550	2300 to 2350	Suitable for large forgings where high strength and high hardness are required and where lesser toughness is not objectionable. Has good wear resistance. Uses: shafts, pinions, gears, etc.
	C 1060	0.55 to 0.65	0.60 to 0.90	0.04	0.05	—	108,000	65,000	Good	Fair	1525 to 1625	1500 to 1575	Water or oil quench 1450 to 1500	2250 to 2300	Suitable for heavy forgings and springs. For heat treated springs, a hardness of 45 to 50 Rockwell C is recommended. Uses: machinery parts, shafts, collars, etc.
	C 1064	0.60 to 0.70	0.50 to 0.70	0.04	0.05	—	100,000	60,000	Fair	Fair	1525 to 1625	1500 to 1575	Water or oil quench 1450 to 1550	2225 to 2250	Suitable for forged hand tools, agricultural implements, springs, etc.
	C 1070	0.65 to 0.75	0.70 to 1.00	0.04	0.05	—	100,000	60,000	Fair	Fair	1525 to 1625	1500 to 1575	Water or oil quench 1450 to 1550	2225 to 2250	Similar to C 1064. Suitable for forged clutch disks, mower sections, plow disks, etc.
High Carbon Steels	C 1080	0.75 to 0.88	0.60 to 0.90	0.04	0.05	—	119,000	70,000	Fair	Fair	1525 to 1625	1500 to 1575	Water or oil quench 1450 to 1550	2225	Suitable for forged plowshares, molds, shovels, harrows, etc.
	C 1085	0.80 to 0.93	0.70 to 1.00	0.04	0.05	—	105,000	60,000	Fair	Fair	1525 to 1625	1500 to 1575	Water or oil quench 1450 to 1550	2150 to 2225	Suitable for forged lock pins, clutch disks, leaf springs, etc.
	C 1095	0.90 to 1.05	0.30 to 0.50	0.04	0.05	—	148,000	75,000	Fair	Fair	1525 to 1625	1500 to 1575	Water or oil quench 1450 to 1550	2075 to 2150	Suitable for forged grass-cutting and grain-cutting tools, pins, keys, springs, carbon steel balls, etc.

Corrosion-Resistant and Heat-Resistant Steels

This general grouping, commonly known as the stainless steels, comprises the iron-base alloys that are designed to resist corrosion at normal temperatures and to resist deformation, scaling and corrosion at higher temperatures. To achieve these properties, chromium and nickel are used as the primary alloying agents. These steels, although readily forgeable, have a rate of heat transfer much slower than that of either the carbon steels or the low alloy steels. This necessitates a longer period of heating for forging, and since they also offer greater resistance to plastic deformation, require more blows or heavier blows to forge. The over-all "stainless" group is generally subdivided into four classifications: (1) ferritic or nonhardenable chromium steels, (2) martensitic or hardenable chromium steels, (3) austenitic or chromium-nickel steels, and (4) special heat resistant alloys. A listing of some typical corrosion resistant and heat resistant steels in each of these categories is shown in Table III.

Nonhardenable Chromium Steels

In these steels, chromium is the chief alloying element for corrosion resistant purposes, ranging from 14 to 27% of the composition. Since the carbon-chromium proportion governs the hardenability of these alloys, they do not harden appreciably during rapid cooling. It is desirable to remove all forging and hot working strains by annealing. These alloys are highly susceptible to grain growth, being frequently "notch-brittle" in large sections. But even though care must be used, they forge more readily than the steels in the other three "stainless" groups. They do not forge as easily as carbon steel. Corrosion resistance in these ferritic alloys surpasses that of the martensitic group, but falls short of that attained by the austenitic class. The nonhardenable chromium steels are all magnetic.

Hardenable Chromium Steels

These steels require extremely careful heating for good forging results. Chromium, the principal alloying element, ranges from 11.5 to 18% of the composition. Here, because of a favorable carbon-chromium proportion, the alloys can be hardened by quenching from high temperatures. The general forging practice used on carbon tool steel is applicable to these alloys. A slight addition of selenium or sulfur improves their machinability, and nickel, up to 2%, is sometimes added to increase toughness. The alloys comprising this group are magnetic. When hot working, extreme care must be taken to avoid overheating.

Chromium-Nickel Steels

This wide grouping is forged with greater difficulty than the straight chromium steels. The primary alloying constituents are nickel and chromium, but small amounts of molybdenum, columbium and titanium are often added for special corrosion resistance. The alloys in this group, nonmagnetic unless cold worked, are commonly referred to as the "18:8" stainless series because of the widespread use of 18 chromium and 8% nickel in their composition. Since these steels cannot be hardened by usual heat treating methods, their use should not be specified for applications requiring high hardness. They have high strength at high temperatures and have better corrosion resistance than the straight chromium series.

Special Heat-Resisting Alloys

Several combinations of chromium-nickel corrosion resistant steels have been developed for extremely high strength-high temperature applications. These alloys have exceptional resistance to creep and fatigue at high temperatures, but like most of the other straight chromium and nickel-chromium corrosion-resisting steels, these special compositions are somewhat difficult to forge.

Iron

Irons are often used for special forging applications where maximum ductility is required. The iron grouping includes ingot iron, wrought iron, iron-copper alloys and the low-carbon steels. The latter have already been discussed elsewhere in this article, but as pointed out previously, a certain amount of overlapping occurs when cataloging engineering materials. The extremely low-carbon steels technically fall in both the steel and iron categories, and it is for this reason they are mentioned here. A listing of data pertaining to both ingot iron and wrought iron is shown in Table IV. Data on the iron-copper alloys, important only insofar as their copper content is concerned, has been omitted from this listing, but is briefly discussed below.

Ingot Iron

Ingot iron is used for forgings where good ductility and moderate strengths are required. It is nonhardening and can be hot worked satisfactorily only within certain specified temperature ranges. If worked outside these fairly well-defined limits, it becomes extremely brittle and cracking results. Ingot iron is forged for such applications as brackets, clamps, braces, etc.

Wrought Iron

Wrought iron furnishes a certain amount of corrosion resistance and has physical properties that are essentially the same as those of pure iron, modified by the quantity and distribution of incorporated slag. Within limits, the ductility of wrought iron is increased by forging or hot working operations because of the finer and more thread-like distribution of the slag that results. The carburizing and hardening temperatures applicable to wrought iron are much the same order as those for AISI No. C1010 steel. Wrought iron is used primarily for forgings where maximum ductility and moderate strengths are required. Typical forged applications include chains, drawbars, bolts, etc.

Iron-Copper Alloys

Copper-bearing iron is used for forging applications where increased resistance to atmospheric corrosion and improved tensile and yield strengths are required without an appreciable corresponding reduction in ductility. The copper content in the compositions of these alloys normally ranges from 0.5 to 4.1%. The resulting tensile strengths run from 57,000 to 69,500 psi., and yield strengths from 40,000 to 55,000 as the copper content rises. Because of the selective oxidation of the iron in these alloys, a concentration of the copper forms on the surface beneath the scale when copper-bearing irons are heated under oxidizing conditions. This copper concentration results in surface checking during hot working when the temperature approaches the melting point of the copper. For this reason, extreme care is required during heating and forging or other hot working operations under oxidizing conditions to prevent this occurrence. Copper-bearing irons and steels are frequently alloyed with nickel in proportions approximately one-third the copper content to prevent or minimize this tendency toward surface checking, since nickel raises the hot working temperature at which surface checking occurs. The iron-copper alloys are usually forged for such applications as chains, bolts, hooks, etc., where only moderate loads are to be applied.

Copper and Copper-Base Alloys

For more moderate strength conditions than those to which the steels are usually subjected, there are many copper-base alloys available as forging materials. These alloys have an important advantage over the majority of the forging steels: Because of their high corrosion-resistance, the copper-base compositions can effectively be used under severely corrosive conditions. The copper-base alloys are further distinguished by their great malleability and high electrical conductivity. From these alloys, forgings for many specialized applications are made. A listing of some typical copper-base alloys suitable for forgings is shown in Table V.

Copper

Because of their substantial immunity to corrosive atmospheres, the commercial cop-

Table II—Typical Alloy Steels for Forgings

Designation	AISI Type No.	Composition: C	Mn	P	S	Si	Ni	Cr	Others	Physical and Mechanical Properties: Tensile Strength, Psi.	Yield Strength, Psi.	Machinability	Forgeability	Heat Treatment: Annealing Temp., Deg. F	Hardening Temp., Deg. F	Tempering Temp., Deg. F	Forging Temp., Deg. F	Characteristics and Applications
Nickel Steels	A2330	0.28 to 0.33	0.60 to 0.80	0.04	0.04	0.20 to 0.35	3.25 to 3.75	—	—	98,000	65,000	Good	Good	1400 to 1500	1450 to 1500	Oil quench to desired hardness	2200	Used for machine parts where toughness is needed to resist impact, shock, fatigue. Heat treatment improves strength and toughness considerably.
	A2340	0.38 to 0.43	0.70 to 0.90	0.04	0.04	0.20 to 0.35	3.25 to 3.75	—	—	110,000	80,000	Good	Good	1400 to 1500	1425 to 1475	Oil quench to desired hardness	2200	Used extensively in machine tool industry for forgings such as shafts and pinions that require high hardness and are subject to shock and impact. These two steels have good toughness.
	A2345	0.43 to 0.48	0.70 to 0.90	0.04	0.04	0.20 to 0.35	3.25 to 3.75	—	—	108,000	75,000	Good	Good	1400 to 1500	1425 to 1475	Oil quench to desired hardness	2200	
	A2515	0.12 to 0.17	0.40 to 0.60	0.04	0.04	0.20 to 0.35	4.75 to 5.25	—	—	92,000	69,000	Machines well, but not as good as plain carburizing grades	Good	Normalize and anneal; carburizing temp. 1650 to 1700 F; cool in box; reheat 1325 to 1375 F; cooling medium—oil; tempering 250 to 400.			2150	Higher nickel content develops better toughness, offers hard surface and high core strength.
Nickel Chromium Steels	A3115	0.13 to 0.18	0.40 to 0.60	0.04	0.04	0.20 to 0.35	1.10 to 1.40	0.55 to 0.75	—	75,000	60,000	Good	Good	Normalize; carburizing temp. 1650 to 1700 F; quench in oil; reheat 1400 to 1450 F; cooling medium—oil; tempering 250 to 300			2220	These steels provide economy and strength; used where plain carbon grades cannot be used because of insufficient strength. Uses: gear and worm parts where conditions are not extreme.
	A3120	0.17 to 0.22	0.60 to 0.80	0.04	0.04	0.20 to 0.35	1.10 to 1.40	0.55 to 0.75	—	75,000	60,000	Good	Good					
	A3130	0.28 to 0.33	0.60 to 0.80	0.04	0.04	0.20 to 0.35	1.10 to 1.40	0.55 to 0.75	—	100,000	72,000	Good	Good	—	1500 to 1550	Water or oil quench to desired hardness	2180	Used where economy and improved strength are required. These steels develop better properties than are obtainable in plain carbon grades, but it is desirable to heat treat them for best results. Interchangeable with No. A2330 in many applications.
	A3135	0.33 to 0.38	0.60 to 0.80	0.04	0.04	0.20 to 0.35	1.10 to 1.40	0.55 to 0.75	—	96,000	64,000	Good	Good	—	1500 to 1550	Oil quench to desired hardness	2180	
	A3140	0.38 to 0.43	0.70 to 0.90	0.04	0.04	0.20 to 0.35	1.10 to 1.40	0.55 to 0.75	—	96,000	64,000	Good	Excellent	1450 to 1550	1500 to 1550	Oil quench to desired hardness	2180	These steels offer fine physical properties and good hardness for an economical alloy steel. They heat treat exceptionally well and are used widely for forgings in the automotive, oil field, railroad, and valve industries.
	A3145	0.43 to 0.48	0.70 to 0.90	0.04	0.04	0.20 to 0.35	1.10 to 1.40	0.70 to 0.90	—	100,000	68,000	Good	Excellent	—	1500 to 1550	Oil quench to desired hardness (gears to 350 to 450)	2180	
	E3310	0.08 to 0.13	0.45 to 0.60	0.025	0.025	0.20 to 0.35	3.25 to 3.75	1.40 to 1.75	—	—	—	Good	Extreme care required	Normalize and anneal; carburizing temp. 1650 to 1700 F; quench in oil; reheat to 1375 to 1425 F; cooling medium—oil; tempering 250 to 300			2220	The high chromium and nickel content of this steel develops good resistance to high pressure, impact, abrasion. Forgings from this steel are ideal for severe operating conditions.
Molybdenum Steels	A4130	0.28 to 0.33	0.40 to 0.60	0.04	0.04	0.20 to 0.35	—	0.81 to 1.10	Mo 0.15 to 0.25	89,000	60,000	Good	Good	1450 to 1550	1550 to 1650	Water or oil quench to desired hardness	2200	This steel can be used interchangeably with Nos. A2330, A3130, and A3135. Preferred for forgings that will be machined in the heat treated state and has good response to heat treatment.

Molybdenum Steels (continued)	A4140	0.38 to 0.43	0.75 to 1.00	0.04	0.04	0.20 to 0.35	—	0.81 to 1.10	Mo 0.15 to 0.25	90,000	63,000	Good	Good	1450 to 1550	1525 to 1625	Oil quench to desired hardness	2200	This steel can be used interchangeably with Nos. A2340 and A3140 for heat treated forgings. Preferred for forgings that are to be machined after being hardened and tempered.
	A4340	0.38 to 0.43	0.60 to 0.80	0.04	0.04	0.20 to 0.35	1.65 to 2.00	0.70 to 0.90	Mo 0.20 to 0.30	115,000	95,000	Good	Requires care	1100 to 1225	1475 to 1525	Oil quench to desired hardness	2200	Combination of Cr-Ni-Mo in this steel offers fine hardenability, high strength, toughness. Best used for forgings where all kinds of stresses are encountered. Can be machined in heat treated state at hardnesses over 400 Bhn. Offers good properties with a hard case.
	A4615	0.13 to 0.18	0.45 to 0.65	0.04	0.04	0.20 to 0.35	1.65 to 2.00	—	Mo 0.20 to 0.30	82,000	55,000	Good	Good	Normalize; carburizing temp. 1650 to 1700 F; quench in oil; reheat 1425 to 1475 F; cooling medium—oil; tempering 250 to 300			2200	These steels are used extensively for most carburizing applications.
	A4620	0.17 to 0.22	0.45 to 0.65	0.04	0.04	0.20 to 0.35	1.65 to 2.00	—	Mo 0.20 to 0.30	82,000	55,000	Good	Good					
	A4815	0.13 to 0.18	0.40 to 0.60	0.04	0.04	0.20 to 0.35	3.25 to 3.75	—	Mo 0.20 to 0.30	105,000	73,000	Good	Fair	Normalize and anneal; carburizing temp. 1650 to 1700 F; quench in oil; reheat 1350 to 1400 F; cooling medium—oil; tempering 250 to 300			2200	Similar in characteristics to No. A2515. Used in applications similar to those of Nos. A4615 and A4620.
Chromium Steels	A5120	0.17 to 0.22	0.70 to 0.90	0.04	0.04	0.20 to 0.35	—	0.70 to 0.90	—	73,000	55,000	Good	Fair	Normalize; carburizing temp. 1650 to 1700 F; quench in oil; reheat 1425 to 1475 F; cooling medium—oil; tempering 250 to 300			2200	This steel is a deep-hardening type similar to No. A3120 except it does not have a tough, fibrous core.
	A5140	0.38 to 0.43	0.70 to 0.90	0.04	0.04	0.20 to 0.35	—	0.70 to 0.90	—	—	—	Fair	Fair	1450 to 1550	1500 to 1600 (gears 1475 to 1525)	Oil quench to desired hardness (gears 350 to 450)	2200	Used interchangeably with Nos. A2340 and A3140 for heat treated forgings requiring greater strength and toughness. Used extensively for gears and shafts hardened by direct cyaniding.
	A5150	0.48 to 0.55	0.70 to 0.90	0.04	0.04	0.20 to 0.35	—	0.70 to 0.90	—	103,000	68,000	Fair	Fair	1450 to 1550	1450 to 1550 (gears 1475 to 1525)	Oil quench to desired hardness (gears 350 to 450)	2200	A deep-hardening steel used extensively for gears, shafts, thrust washers, springs, etc.
	E52098	0.95 to 1.10	0.25 to 0.45	0.04	0.04	0.20 to 0.35	—	0.90 to 1.15	—	109,000	80,000	Fair	Fair	1350 to 1450	1425 to 1475 or 1500 to 1600	Water or oil quench to desired hardness	2200	This electric furnace steel is used for races and balls or rollers in antifriction bearings. Chromium and high carbon content cause maximum penetration effect of heat treatment and develop an extremely high degree of hardness.
Chromium-Vanadium Steel	SAE 6150	0.48 to 0.55	0.65 to 0.90	0.04	0.04	0.20 to 0.35	—	0.80 to 1.10	V 0.15	103,000	70,000	Fair	Fair	1550 to 1650	1550 to 1650	Oil quench to desired hardness	2220	Suitable for heat treated forgings and machined parts subjected to severe conditions where high strength and antifatigue properties are essential. Used for leaf and coil springs, gears, shafts, heavy forgings.
Silicon-Manganese Steel	A9260	0.55 to 0.65	0.70 to 1.00	0.04	0.04	1.80 to 2.20	—	—	—	142,000	92,000	Fair	Fair	—	1500 to 1650	Oil quench to desired hardness	2150	This steel has been standardized in usage principally for leaf springs.

pers suitable for forgings applications are extensively used where conditions of this type exist. However, their use is not recommended in contact with oxidizing acids and most oxidizing agents or in services where alternate exposure to oxidizing conditions and acid reagents takes place. The forgeable coppers have excellent hot and cold working characteristics, being plastic through a wide range of temperature and possessing no critical range in which plasticity is seriously reduced. As a consequence, the alloys forge and machine readily. But they possess only moderate strength and hardness.

Brasses

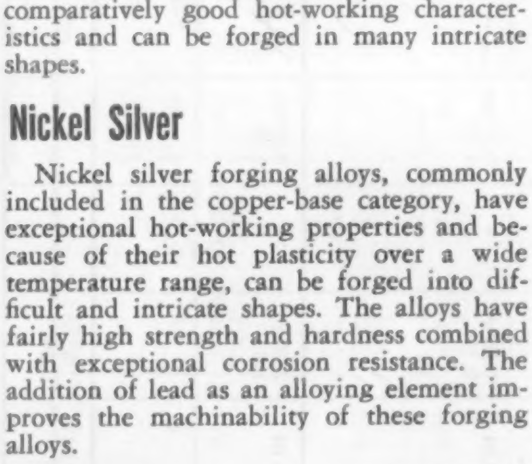
Most widely-used and best-known of the copper-base alloys are the brasses. In these, the inclusion of zinc increases the tensile properties but with a corresponding reduction in the electrical and thermal characteristics of the alloys. Brasses are usually used where it is desired to improve some specific characteristic of copper and where such improvement can be made without unduly sacrificing the other copper characteristics. The machinability of the brasses is dependent upon the lead content: the higher the lead, the better the machinability. Brass alloys forge readily and are particularly adaptable to the economical press forging technique. Cost-wise, they are the cheapest of the forgeable copper-base alloys.

Bronzes

The bronze forging alloys are available in many combinations and are generally stronger than the brasses. They also offer better corrosion-resisting properties and have better wear resistance than that exhibited by the brass alloys. On the average, the bronze forging alloys possess higher mechanical properties than the other forgeable copper-base compositions. They have comparatively good hot-working characteristics and can be forged in many intricate shapes.

Nickel Silver

Nickel silver forging alloys, commonly included in the copper-base category, have exceptional hot-working properties and because of their hot plasticity over a wide temperature range, can be forged into difficult and intricate shapes. The alloys have fairly high strength and hardness combined with exceptional corrosion resistance. The addition of lead as an alloying element improves the machinability of these forging alloys.



Brass forging (right) was made on a hammer with attendant necessary draft. Brass forging (left) was designed for same use but was made in two press forge operations. (Courtesy of Scovill Manufacturing Co.)

Nickel and Nickel-Base Alloys

The corrosion resisting nickel and nickel-base alloys can be forged readily into almost any shape that can be forged in steel. Forgings of the high-nickel materials are stronger than those of bronze or of carbon steel that have not been heat treated subsequently, but since they are usually stiffer than steel at forging temperatures, successful nickel-base forgings are largely dependent upon proper heating, *i.e.* careful control over heating time and temperature and control of furnace atmosphere.

The materials of high nickel content have a great susceptibility to attack by sulfur at heating temperatures, a peculiar intercrystalline brittleness resulting if exposed to oxidizing or sulfurizing gases. The pores of the metal oxidize or sulfurize and a brittle surface layer is produced which cannot be deformed by subsequent forming operations. For this reason, extreme care is required in heating operations. Where service conditions are such that forgings of these nickel materials must withstand both high temperatures and abovementioned detrimental atmospheres, manganese up to 4.5% is customarily included in the alloy composition.

Certain commercial nickel and nickel alloy forgings can be increased in mechanical properties by prescribed precipitation hardening thermal treatments.

These forgings have excellent properties that persist even at high temperatures where many other metals become weak, plastic, or oxidize rapidly.

Light Alloys

The light forging materials, alloys of aluminum and magnesium, are characterized by their extremely light weight, high strength, and general resistance to corrosion. Their use is most usually indicated where weight is a prime factor. The choice of alloy, of course, is conditioned by the properties desired in the finished forging and by the ability of the material in question to be forged to the desired size and shape. A listing of some typical aluminum and magnesium forging alloys is shown in Table VII.

Aluminum

Aluminum alloy forgings are usually used where reduction in weight and comparatively high strength are major considerations of product design. The weight of these forgings is approximately one-third that of similar ones in brass. As in the case of most materials, the selection of an aluminum forging alloy is dependent upon the properties desired in the finished forging. The high tensile strength aluminum alloys do not possess the corrosion resistance of the lower strength compositions, and since some of the alloys do not forge as easily as others, care should be taken to confine their use to the less intricate forging patterns.

Most of the aluminum alloys commonly used for forgings have reasonably good corrosion resistance, and forge and machine fairly readily. Forging techniques and die design for both press and drop hammer operations on aluminum alloys are similar to those employed for steel. But compared with common steel, aluminum alloys require about 30% more power to forge. Following forging, heat treatment is usually required to develop certain required mechanical properties.

Magnesium

Magnesium alloys are readily forgeable to give high strength forgings with uniform properties, pressure tightness, and good fatigue strength. Limitations of shape complexity are the same as for most other metals, and design should be kept as simple as possible to facilitate production. As in the case of most other forged metals, directional properties exist in magnesium forgings. The highest properties are obtained in the most thoroughly worked sections and in the direction of maximum metal flow. Magnesium forgings are generally used for highly stressed applications. Hence, good design is essential so as to eliminate stress concentrations and provide oversize radii and fillets. In general, magnesium forgings are produced from extruded rod for applications where strength and light weight are desired, such as aircraft engine parts, control fittings, hydraulic valve parts, and supercharger components.

Magnesium alloys are usually forged with hammers, mechanical presses or hydraulic presses, the strongest of the alloys being forged on hydraulic presses. Moderately high properties are obtained in mechanical press forgings and in hammer forgings. The former are forged to close dimensional tolerances. As a result, minimum machining is usually required.

Processing of Forgings

Forgings sometimes can be utilized directly as they come from the dies without being subjected to any further processing or special handling. But in most instances, forgings require some form of finishing before they can be used for their intended purpose. Finishing operations may include only a single operation or a combination of several, depending again upon the material from which the forging was made, the complexity of the design, and the type of service to which it will be subjected. In total, these finishing operations usually comprise trimming, some form of heat treatment, coining, grinding, straightening, machining, cleaning, polishing or buffing, and plating, if required. These operations, although not necessarily performed in the

Table III—Typical Corrosion Resistant and Heat Resistant Steels for Forgings

Designation	AISI Type No.	Composition: C	Cr	Ni	Mn	Si	P	S	Se	Others	Physical and Mechanical Properties: Tensile Str., Psi.	Yield Str., Psi.	Melting Range, Deg. F	Forgeability	Machinability	Heat Treatment: Annealing	Hardening	Tempering	Forging Data: Pre-heat Temp., Deg. F	Initial Forging, Deg. F	Finish Forging, Deg. F	Characteristics and Applications
Nonhardenable Chromium Steels (Ferritic Structure)	430	0.12 max.	14.0 to 18.0	—	1.0	1.0	0.04	0.03	—	—	80,000	50,000	2650 to 2700	More readily than martensitic or austenitic. Not as easy as carbon steel	Fair	Furnace-cooled 1450	Nonhardening	Nonhardening	1400	1900 to 2050	1300 to 1450	An easily-formed stainless alloy extensively used for automobile trim, aircraft parts, steel markers, etc.
	446	0.35 max.	23.0 to 27.0	0.25	1.50	1.0	0.04	0.03	—	—	85,000	50,000	2650 to 2700	More readily than martensitic or austenitic. Not as easy as carbon steel	Fair	Air-cooled 1450 to 1550	Nonhardening	Nonhardening	1400	1900 to 2050	1300 to 1450	Has high resistance to corrosion and scaling resistance up to 2150 F. Used widely for chemical and laboratory equipment, etc.
Hardenable Chromium Steels (Martensitic Structure)	410	0.15 max.	11.5 to 13.5	—	1.0	1.0	0.04	0.03	—	—	75,000	40,000	2700 to 2750	About same as for carbon steel	Fair	Air-cooled 1200 to 1250	Oil quench 1750 to 1825	400 to 1200	1500	2050 to 2150	1600 to 1700	A low-priced, general purpose, heat treatable stainless steel. Used for low-cost cutlery, etc.
	416	0.15 max.	12.0 to 14.0	—	—	—	0.07	0.07	0.07	—	75,000	40,000	2700 to 2750	Not recommended for severe forging deformation	Good	Furnace-cool 1450 to 1100	Oil quench 1800 to 1850	Up to 1200	1500	2050 to 2150	1600 to 1700	Similar to No. 410 but a free-machining grade. Not particularly good for complex forging.
	420	More than 0.15	12.0 to 14.0	—	—	—	—	—	—	—	100.000	65,000	2700 to 2750	Not recommended for severe forging deformation	Fair	Furnace-cool 1450 to 1100	Oil quench 1775 to 1850	350 to 800	1500	2000 to 2100	1600 to 1700	Used extensively for cutlery, surgical instruments, valve parts, ball bearings, magnets, etc.
	440	0.60 to 1.20	16.0 to 18.0	—	—	—	—	—	—	Mo 0.75	125,000	70,000	2650 to 2700	Not recommended for severe forging deformation	Fair	Air-cooled 1400	Oil quench 1875 to 1925	350 to 800	1500	1950 to 2050	1600 to 1700	This steel has very high hardness obtainable in the high carbon grades. Used widely for instruments, cutlery, valve parts, etc.
Chromium-Nickel Steels (Austenitic Structure)	302	0.08 to 0.02	17.0 to 19.0	8.0 to 10.0	2.0	1.0	0.04	0.03	—	—	80,000	30,000	2250 to 2600	Difficult	Fair, tough	1850 to 1950	Nonhardening except by cold working	Nonhardening	1500	2150 to 2200	1600 to 1700	A readily fabricated stainless steel of the 18:8 type. Used primarily for corrosion resistant applications.
	303	0.15 max.	17.0 to 19.0	8.0 to 10.0	—	—	0.07 min.	0.07 min.	0.07 min.	Zr, Mo 0.60 max.	80,000	30,000	2250 to 2600	Not recommended for severe forging deformation	Good	1900 to 1950	Nonhardening except by cold working	Nonhardening	1500	2150 to 2250	1600 to 1700	A free-machining grade of 18:8 stainless steel. Not particularly good for complex forging.
	309	0.20 max.	22.0 to 24.0	12.0 to 15.0	2.0	1.0	0.04	0.03	—	—	100,000	50,000	2500 to 2550	Difficult	Fair, tough	1900 to 2050	Nonhardening except by cold working	Nonhardening	1500	2100 to 2150	1700	This steel combines high scaling resistance with good strength. Used primarily for high temperature applications.
	310	0.25 max.	24.0 to 26.0	19.0 to 22.0	2.0	1.50	0.04	0.03	—	—	100,000	50,000	2500 to 2600	Difficult	Fair, tough	1900 to 2050	Nonhardening except by cold working	Nonhardening	1500	2100 to 2150	1700	Similar to 25:12 stainless with higher nickel content for greater stability.
	321	0.08 max.	17.0 to 19.0	8.0 to 11.0	2.0	1.0	0.04	0.03	—	Ti 5xC min.	85,000	40,000	2500 to 2550	Difficult	Fair, tough	1950 to 2050	Nonhardening except by cold working	Nonhardening	1500	2150 to 2200	1600 to 1700	An 18:8 type stainless steel stabilized against intercrystalline corrosion at elevated temperatures.

order listed, are often used to meet certain specifications that are required for the final forged part.

Heat Treating

In order to develop certain desired physical properties in the forged metal, special heat treatments are often required. These may involve normalizing, annealing, quenching or tempering in order that the desired properties of strength, toughness, fatigue resistance, wear resistance, and machinability are imparted to the forging according to its service requirements. Some forged materials require more than one type of treatment to develop specific characteristics, while others need only one to meet the job requirements. But throughout the heat treating process, the fibrous structure developed by the forging process is unaltered since the heat treatment controls only the grain structure of the metal and does not impair the fiber-like flow of the forged material.

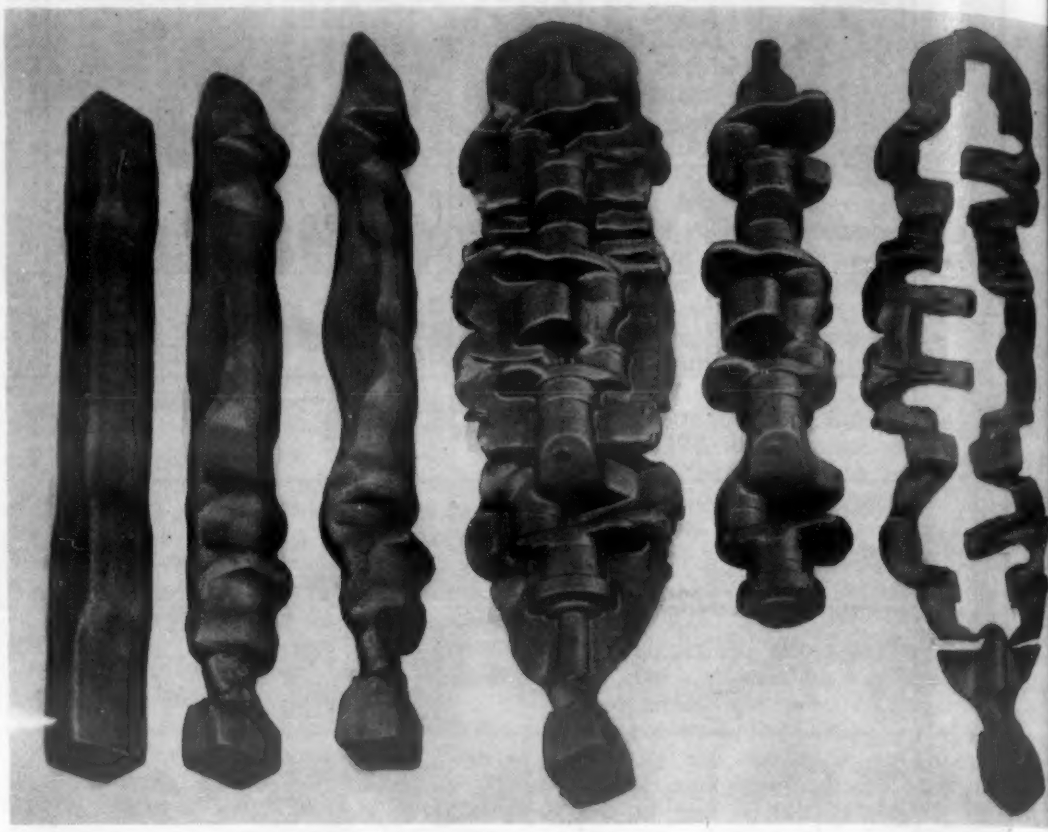
Normalizing is used to relieve forging strains or other internal strains by refining the internal grain to provide a uniformity of size. It is also used to provide better machinability in the forged part. Annealing also relieves processing strains and provides better machinability, but although somewhat similar to normalizing, it leaves the forged metal in a much softer state.

Quenching is a hardening operation that is used to obtain the optimum ratio of hardness, strength and resistance to fatigue. Tempering, following hardening, relieves the quenching strains and develops the degree of toughness desired in the finished part. Impact strength is also increased by quenching and tempering.

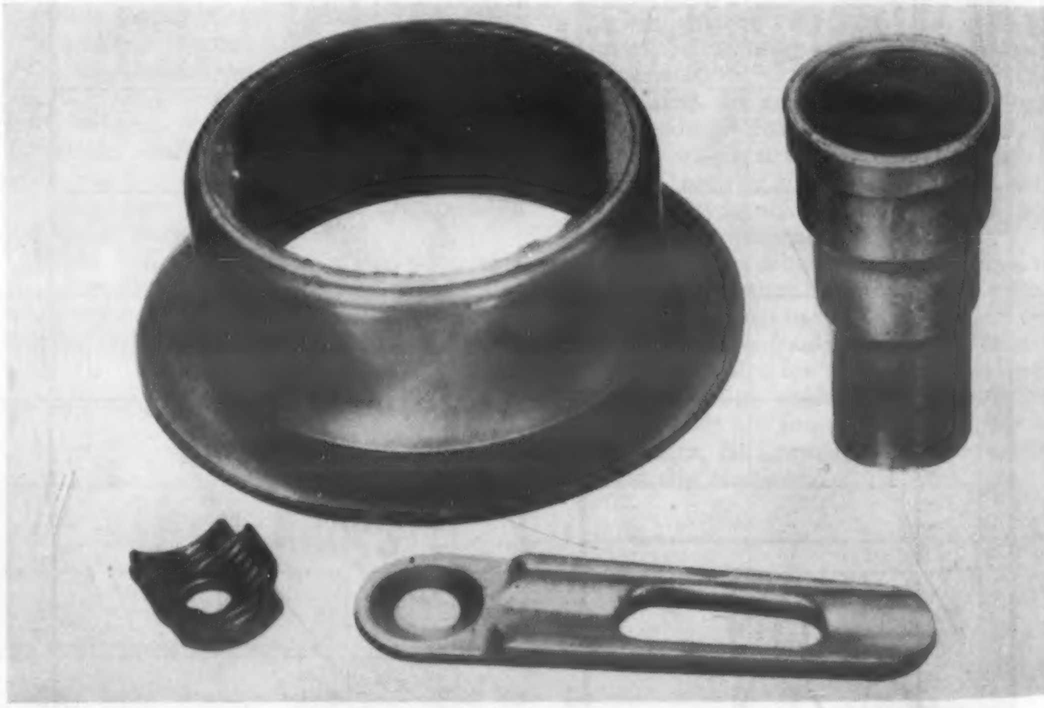
All heat treating operations are dependent upon proper length of time for heating and cooling and proper temperature control. These variables, in turn, depend upon the material used, the size and shape of the forging, and the properties desired in the finished part. All of these factors must be considered for satisfactory heat treating results.

Coining, Grinding and Straightening

Coining, grinding and straightening operations are often performed on forged parts to reduce subsequent and expensive machining work. Through the use of coining presses, very close tolerances can be obtained on the thickness dimensions of some forgings. The coining dies allow a flow of metal on the surfaces being coined to move to adjacent surfaces on which no pressure is exerted. The dimensions which are coined, obviously, must be between opposed



Successive steps in the hammer-forging of an automobile crankshaft from SAE 1045 (AISI No. C1045) steel, starting with the bar stock (left) and progressing through the removal of the flash (right). (Courtesy of Wyman-Gordon Co.)



Four different types of nonferrous forgings. Brass flanged forging (upper left) has web pierced from bottom. Stepped forging (upper right) has cavity almost all the way through with a web about ½ in. up from small end on inside. Long brass forging (lower right) has web pierced from oblong hole. Small copper forging (lower right) has web pierced from hole. (Courtesy of Scovill Manufacturing Co.)

Table IV—Typical Irons for Forgings

Designation	Composition					Physical and Mechanical Properties				Heat Treatment				
	C	Mn	P	S	Si	Tensile Str., Psi.	Yield Str., Psi.	Machin-ability	Forge-ability	Normal-izing Temp., Deg. F	Anneal-ing Temp., Deg. F	Quench-ing Temp., Deg. F	Forging Temp., Deg. F	Characteristics and Applications
Ingot Iron	0.015	0.025	0.005	0.025	0.003	41,000 to 45,000	18,000 to 25,000	Good	Good	—	1750	Nonhard-ening	1920 to 2500	Has good ductility within specified hot working limits. Nonhardening, but has moderate strength. Used for brackets, clamps, braces, etc.
Wrought Iron	0.060 to 0.080	0.150 to 0.045	0.062 to 0.115	0.010 to 0.015	0.101 to 0.183	42,000 to 52,000	26,000 to 35,000	Good	Good	1650 to 1750	1000 to 1350	Water quench 1650 to 1700	2400	Has a certain amount of corrosion resistance. Carburizing and hardening temperatures about same as for AISI No. C1010 steel. Used where ductility is required for forging chains, bolts, drawbars, etc.

Table V—Typical Copper-Base Alloys for Forgings

Designation	Metal	Composition: Cu	Zn	Sn	Pb	Others	Physical and Mechanical Properties: As Forged Tensile Strength, Psi.	As Forged Yield Strength, Psi.	Annealing Temp., Deg. F	Melting Temp., Deg. F	Machinability	Forgeability	Forging Temp., Deg. F	Characteristics and Applications
Coppers	Electrolytic (tough pitch) copper	99.92	—	—	—	—	30,000 to 38,000	10,000	700 to 1200	1981	Fair	Good	1400 to 1600	These two forms of copper have excellent hot-working properties but only moderate strength. Used primarily where high strength and high hardness are not required for such uses as plumbing fixtures, electrical applications, etc. Deoxidized copper better for welding operations.
	Deoxidized copper	99.94	—	—	—	—	30,000 to 38,000	10,000	700 to 1200	1981	Fair	Good	1400 to 1600	
Brasses	Muntz Metal	60.0	40.0	—	—	—	45,000 to 60,000	20,000 to 30,000	800 to 1100	1660	Fair	Excellent	1150 to 1450	Excellent hot-working properties. Used where higher strength, stiffness, resistance to sea water are required in such applications as valves, marine fittings and equipment, etc.
	Forging brass	60.0	38.0	—	2.0	—	45,000 to 60,000	20,000 to 30,000	800 to 1100	1640	Excellent	Excellent	1200 to 1500	Has fairly high strength, good corrosion resistance, excellent hot-working characteristics. Used where no particular hardness or severe corrosion resistance is needed. Used for hardware, decorative applications, etc.
	Naval brass	60.0	39.25	0.75	—	—	50,000 to 65,000	25,000 to 35,000	800 to 1100	1650	Fair	Excellent	1200 to 1500	Has high hardness and excellent resistance to salt water. Used where slightly higher strengths are required than those offered by forging brass, particularly in marine applications.
	Leaded Naval brass	60.0	37.50	0.75	1.75	—	50,000 to 65,000	25,000 to 35,000	800 to 1100	1650	Excellent	Good	1200 to 1400	This alloy has approximately the same characteristics as Naval brass, but better machinability. Used for intricate marine applications primarily.
Bronzes	High silicon bronze	96.0	—	—	—	Si 3.0, others 1.0	50,000 to 65,000	18,000 to 24,000	900 to 1300	1880	Fair	Good	1300 to 1600	Has excellent corrosion resistance, toughness, resistance to fatigue. Used where higher strength and hardness not a factor in such applications as the chemical industries, marine equipment, salt, oil refineries, etc.
	Low silicon bronze	97.7	—	—	—	Si 1.5, others 0.8	40,000 to 55,000	16,000 to 22,000	900 to 1250	1940	Fair	Good	1300 to 1600	This alloy has exceptional corrosion resistance. Used primarily for such applications as marine hardware, pole-line hardware, etc.
	Aluminum bronze	89.5	—	—	—	Al 9.0 Fe 1.0	75,000 to 90,000	33,000 to 40,000	800 to 1100	1900	Fair	Good	1450 to 1600	This high strength alloy is very corrosion resistant, has good compressive loading characteristics, and is free of zinc. It is lighter in weight than the other copper-base alloys and withstands high temperatures without scaling. Used extensively for aircraft parts, machine tools, etc.
	Manganese bronze, A	58.5	39.2	1.0	—	Fe 1.0	60,000 to 75,000	35,000 to 45,000	800 to 1100	1630	Fair, about same as Naval brass	Excellent	1150 to 1450	A high strength alloy with high hardness properties, good corrosion and shock resistance. Used extensively in marine field for equipment, fittings, hardware, etc.
Nickel Silver	Leaded nickel silver 10%	45.0	42.5	—	2.5	Ni 10.0	65,000 to 75,000	40,000 to 50,000	—	1650	Good	Good	1350 to 1500	Not technically classified as a bronze, but similar in many respects. Has good corrosion resistance, high strength and hardness. Used extensively for valve parts and fittings in food and chemical industries, etc.

Table VI—Typical Nickel-Base Alloys for Forgings

Metal	Composition										Physical and Mechanical Properties				Annealing Temp., Deg. F	Melting Temp., Deg. F	Forging Temp., Deg. F	Characteristics and Applications
	Ni	Cu	Fe	Al	Mn	Cr	Mo	W	Si	C	Tensile Strength, Psi.	Yield Strength, Psi.	Machin-ability	Forge-ability				
"A" Nickel	99.4	0.1	0.15	—	0.25	—	—	—	0.05	0.05	60,000 to 90,000	20,000 to 80,000	Good	Good	1200 to 1400	2635	Light forgings 1200 to 1600 Heavy forgings 1600 to 2300	Has good malleability, heat and corrosion resistance. Used extensively in the chemical and plating industries, etc.
"D" Nickel	94.2	0.05	0.15	—	4.5	—	—	—	0.05	0.10	86,000	34,000	Good	Good	1400 to 1500	2600	Light forgings 1200 to 1700 Heavy forgings 1700 to 2150	Good resistance to sulfur compounds at high temperatures under both oxidizing and reducing conditions; used for chemical industry apparatus.
"Z" Nickel	93.7	0.05	0.35	4.4	0.3	—	—	—	0.5	0.17	90,000 to 200,000*	35,000 to 150,000*	Good	Good	1600 for 1-hr. quench in water	2635	Light forgings 1600 to 1900 Heavy forgings 1900 to 2300	This age hardening high-nickel alloy has great strength and hardness combined with high corrosion resistance. Used for pump rods, springs, shafts, etc.
Monel	67.0	30.0	1.4	—	1.0	—	—	—	0.1	0.15	75,000 to 110,000	40,000 to 85,000	Good	Good	1600 for 10 min., 1800 for 1-4 min.	2370 to 2460	Light forgings 1200 to 1700 Heavy forgings 1700 to 2150	Has high strength and high hardness combined with good corrosion resistance. Used in the chemical, marine, laundry, food industries, etc.
"K" Monel	66.0	29.0	0.9	2.75	0.75	—	—	—	0.5	0.15	90,000 to 165,000*	40,000 to 125,000*	Fair	Good	1600 for 1-hr. quench in water	2460	Light forgings 1350 to 1900 Heavy forgings 1900 to 2150	Nonmagnetic, age hardening alloy with corrosion resistance similar to Monel. Used widely for aircraft parts, pump rods, springs, valve stems, etc.
"KR" Monel	66.0	29.0	0.9	2.75	0.75	—	—	—	0.5	0.28	90,000 to 160,000*	40,000 to 120,000*	Fair	Good	1600 for 1-hr. quench in water	2460	Light forgings 1350 to 1900 Heavy forgings 1900 to 2150	Same characteristics as "K" Monel but a free-cutting grade.
80 Ni 20 Cr	78.0	—	0.75	—	2.0	19.5	—	—	1.0	0.15	95,000	20,000 to 80,000	Fair	Good	1600 to 1900	2250	2200	Has good corrosion resistance and moderate strength characteristics. Used for high temperature applications such as heating elements, etc.
Inconel	78.0	0.2	7.0	—	0.25	14.0	—	—	0.25	0.08	85,000 to 120,000	35,000 to 90,000	Fair	Good	1600 for 3 hr. to 1800 for 15 min.	2540 to 2600	Light forgings 1600 to 1850 Heavy forgings 1850 to 2300	This high strength, nonmagnetic, corrosion-resistant alloy is good at high temperatures without scaling or intercrystalline attack.
60 Ni 15 Cr	58.0	—	22.0	—	2.5	16.0	—	—	1.1	0.25	105,000	20,000 to 80,000	Good	Good	1200 to 2000	2750 to 2800	Light forgings 1600 to 1850 Heavy forgings 1850 to 2300	Has good corrosion resistance and moderate strength characteristics. Used for heating elements, machine parts, etc.
Hastelloy A	57.0	—	20.0	—	—	—	20.0	—	—	—	110,000 to 120,000	47,000 to 50,000	Good	Good	2150	2900 to 3000	Light forgings 1600 to 1900 Heavy forgings 1900 to 2250	Resistant to nonoxidizing acids and salts. Used extensively in chemical process industries.
Hastelloy B	62.0	—	5.0	—	—	—	30.0	—	—	0.12	130,000 to 140,000	60,000 to 65,000	Good	Good	2150	2900 to 3000	Light forgings 1600 to 1900 Heavy forgings 1900 to 2250	Resistant to nonoxidizing acids and salts. Used extensively in chemcal process industries.
Hastelloy C	58.0	—	5.0	—	—	15.0	17.0	5.0	—	0.15	115,000 to 128,000	55,000 to 65,000	Good	Fair	2225	2900 to 3000	Light forgings 1700 to 2000 Heavy forgings 2000 to 2250	Resistant to oxidizing acids and salts, and also to sea water.

* Forged, heat treated.

Table VII—Typical Light Alloys for Forgings

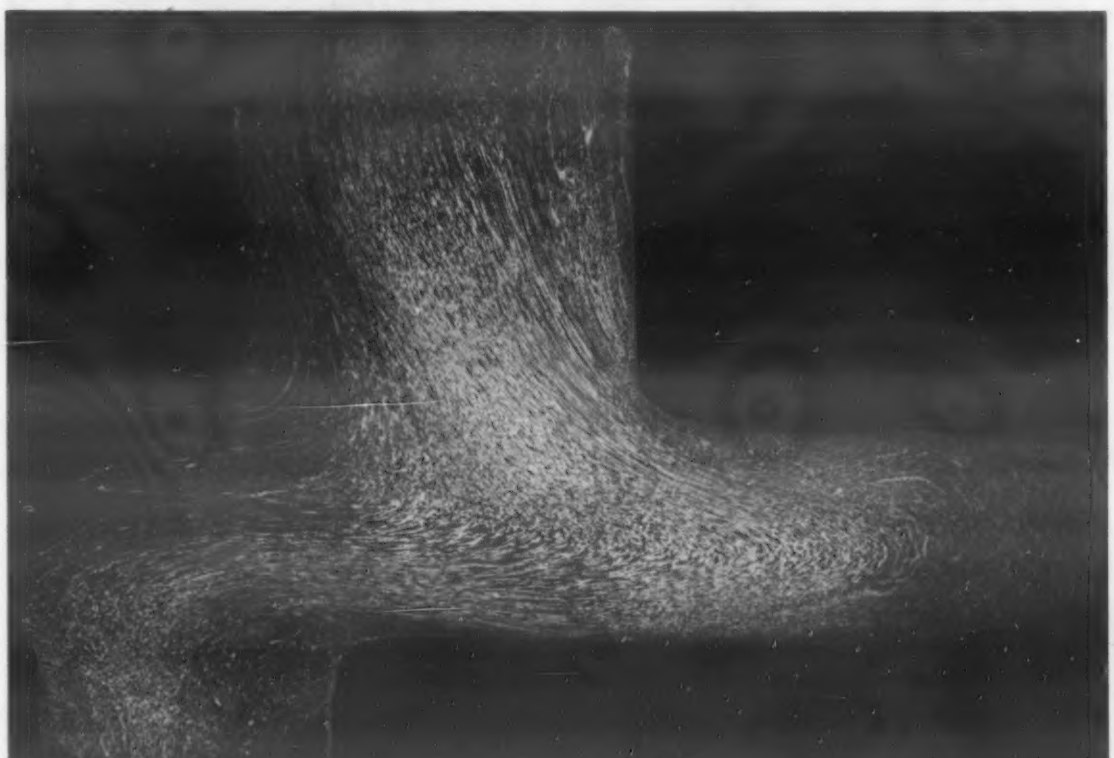
Heavy forgings 2000 to 2250

* Forged, heat treated.

Table VII—Typical Light Alloys for Forgings

Designation	Alloy No.	Composition: Al	Fe + Si	Cu	Mn	Zu	Others	Physical and Mechanical Properties: Ultimate Strength, Psi.	Yield Strength, Psi.	Machinability	Forgeability	Annealing Temp., Deg. F	Forging Data: Hammer Forging Temp., Deg. F	Press Forging Temp., Deg. F	Characteristics and Applications
Aluminum Alloys	2S	Bal.	1.00	0.20	0.05	0.10	0.15	13,000	5,000	Good	Good	650	680 to 840	680 to 840	Good corrosion resistance but poor strength; used primarily for low strength applications in food and chemical equipment, etc.
	3S	Bal.	1.30	0.20	1.50	0.10	0.15	16,000	6,000	Good	Good	750	680 to 840	680 to 840	Possesses more strength than No. 2S but has relatively same amount of corrosion resistance. Uses are similar.
	14S	Bal.	2.20	5.00	1.20	0.25	Mg 0.75, others 0.15	Temper T4 62,000	Temper T4 44,000	Fair	Not suitable for intricate forgings	Complete annealing 750 to 800, furnace cool to 500	760 to 820	800 to 860	Has high strength combined with high hardness. Used extensively for power-shovel bails, aircraft parts, etc.
	17S	Bal.	1.75	4.70	1.00	0.25	Mg 0.75, others 0.15	26,000	10,000	Good	Good	Complete annealing 750 to 800, furnace cool to 500	760 to 820	800 to 860	Has high strength and hardness as well as good corrosion resistance. Used for hardware, aircraft parts, transportation equipment.
	24S	Bal.	1.00	4.90	—	0.09	Mg 1.80, others 0.10	27,000	11,000	Good	Good	Complete annealing 750 to 800, furnace cool to 500	760 to 820	800 to 860	Possesses higher strength than No. 17S but has approximately same other characteristics. Used for aircraft structures, rivets, hardware, etc.
	18S	Bal.	1.90	4.50	0.25	0.25	Mg 0.90, others 0.15	Temper T61 62,000	Temper T61 48,000	Good	Good	Complete annealing 750 to 800, furnace cool to 500	760 to 820	800 to 860	High strength at elevated temperatures. Used particularly for forged cylinder heads, pistons, etc.
	25S	Bal.	2.20	5.00	1.20	0.25	Mg 0.50, others 0.15	Temper T6 58,000	Temper T6 37,000	Good	Readily forged	Complete annealing 750 to 800, furnace cool to 500	800 to 866	820 to 880	Good hot working characteristics with fairly high strength. Used for airplane propellers, link rods, radial-engine crankcases, etc.
	32S	Bal.	14.50	1.30	0.20	0.25	Mg 1.30, others 0.15	Temper T6 55,000	Temper T6 46,000	Good	Good	Complete annealing 750 to 800, furnace cool to 500	800 to 860	820 to 880	Has good forgeability and low coefficient of thermal expansion. Used where these are required, particularly as in case of forged pistons, etc.
	A51S	Bal.	2.20	0.35	0.20	0.25	Mg 0.80, others 0.15	Temper T6 48,000	Temper T6 43,000	Excellent	Most readily forged	Complete annealing 750 to 800, furnace cool to 500	780 to 840	820 to 880	Has good forgeability, good strength and good corrosion resistance; particularly adapted to forging thin sections. Used for crankcases, fuse parts, etc.
	53S	Bal.	1.30	0.10	—	0.25	Mg 1.40	16,000	7,000	Good	Good	Complete annealing 750 to 800, furnace cool to 500	800 to 860	820 to 880	Moderate strength but good corrosion resistance. Used widely in petroleum fields and for marine equipment.
	61S	Bal.	1.50	0.40	0.15	0.20	Mg 1.20, others 0.15	Temper T6 45,000	Temper T6 40,000	Good	Good	Complete annealing 750 to 800, furnace cool to 500	800 to 860	820 to 880	Good strength, good workability, and very good corrosion resistance. Used extensively for aircraft and marine parts, etc.
	R317	Bal.	2.00	3.50 to 4.50	0.40 to 1.00	0.20	Mg 0.2 to 0.8, Bi 0.3 to 0.7, Pb 0.3 to 0.7	Quenched 61,000	Quenched 35,000	Excellent	Excellent	750 to 800	675 to 750	—	Good corrosion resistance and excellent hot working properties. Used for screw machine products and general forgings application.
Magnesium Alloys	AZ61X	5.80	Si 0.30	0.05	0.15	0.04	Ni 0.005, others 0.30	43,000	26,000	Good	Good	Stress relieved at 500 F in 15 min. Annealing temp. 650	Hot working temperatures 450 to 750		Has good mechanical properties and high resistance to corrosion. Used widely for press forgings.
	M1	—	Si 0.03	0.05	1.20	—	Ni 0.01, others 0.30	36,000	23,000	Good	Good	Stress relieved at 500 F in 15 min. Annealing temp. 700	Hot working temperatures 560 to 1000		A low-cost alloy having moderate properties. Used extensively for economical and medium-duty forgings.
	AZ80X	9.20	Si 0.03	0.05	0.10	0.80	Ni 0.005, others 0.30	46,000	31,000	Good	Fair	Solution heat treatment 750 F; 2 to 4 hr. air cooled. Annealing temp. 725	Hot working temperatures 600 to 750		Has the highest strength of the wrought magnesium alloys. Used primarily for heat treatable press forgings.
	TA54	4.0	Si 0.30	0.05	0.40	—	Ni 0.005, others 0.30	40,000	28,000	Good	Good	650	Hot working temperatures 450 to 820		A general purpose hammer-forging alloy of intermediate strength.

Automotive spindle forgings being produced on a 4000-lb. steam hammer. Furnace (left) heats blanks to suitable temperature prior to forging operation. (Courtesy of Heppenstall Co.)



Grain direction or flow shown in sectioned and etched steel forging. This characteristic distinguishes forged parts from those produced by other fabrication processes. (Courtesy of Wyman-Gordon Co.)

surfaces and adjacent to surfaces to which the excess metal may move. But despite this limitation, coining affects savings on many types of forgings by replacing costly machining. Grinding, straightening, chipping and snagging operations are often required for removing any burrs which may have been left at the parting line when the forging was trimmed, for roughing to dimensions, and for fairing-up bent or damaged sections.

Machining

Most forgings require a certain amount of machining before the part is ready for ultimate use. For this reason, the relative machinability of the forged metal is of extreme importance, since forgings that prove difficult to machine result in higher unit costs and lower production rates. The machinability of a forging depends upon the hardness and toughness of its particular composition, the types of machining operations to which it will be subjected and the size, shape and ultimate use of the particular part in question. The machining of a forging also includes a consideration of its machinability hardness range, the amount of excess metal that must be left on the various surfaces of the part during the forging operation to provide for subsequent machining, the cost and availability of the various jigs and fixtures required in machining operations, and the relative cost and accuracy of dimensional tolerances obtained through forging above as compared to such tolerances obtained through subsequent machining operations.

The amount of excess metal usually allowed for machining purposes varies with the size and shape of the forging and with the general type of machining to be performed. Sufficient metal is usually provided to accommodate any scale pits or other irregularities in the surface that might be formed during the forging operation. In all cases, however, the amount of excess metal is usually held to a minimum to reduce machining time and to conserve material.

Cleaning, Plating and Polishing

Forgings usually acquire considerable scale, grime, oil and surface dirt both during forging and subsequent handling operations. To remove this extraneous matter, various types of cleaning operations are performed. Tumbling and shot or sand blasting are considered to give the best finished surface. Tumbling is usually restricted to small forgings having no thin web-like sections that are likely to bend. Tumbling or blasting operations, if prolonged, will increase the surface hardness and fatigue resistance of the forged pieces. For some metals, pickling in various solutions will effectively remove forging and heat treating scale. Degreasing, rust proofing, bright dipping, plating, polishing and buffing are also used for finishing forgings to certain required specifications.

Acknowledgment

Acknowledgment is made for the assistance given in the preparation of this manual by the following organizations:

Aluminum Co. of America, Pittsburgh, Pa.
American Forge & Manufacturing Co., Pittsburgh, Pa.
American Iron & Steel Institute, New York, N. Y.
American Magnesium Corp., New York, N. Y.
Atwater Manufacturing Co., Plantsville, Conn.
Benson Manufacturing Co., Kansas City, Mo.
Brass Forging Assn., New York, N. Y.
Carnegie-Illinois Steel Corp., Pittsburgh, Pa.
E. D. Clapp Manufacturing Co., Auburn, N. Y.
Davenport, Besler Corp., Davenport, Iowa
Dow Chemical Co., Midland, Mich.
Drop Forging Assn., Cleveland, Ohio
Drop Forge Div., Willys-Overland Motors, Inc., Toledo, Ohio
Endicott Forging & Manufacturing Co., Endicott, N. Y.
Forging Manufacturers' Assn., New York, N. Y.
Heppenstall Co., Pittsburgh, Pa.
International Nickel Co., Inc., New York, N. Y.
Interstate Drop Forge Co., Milwaukee, Wis.
Kropp Forge Co., Chicago, Ill.
Mesta Machine Co., Pittsburgh, Pa.
Moore Drop Forging Co., Springfield, Mass.
Mueller Brass Co., Port Huron, Mich.
National Lock Washer Co., Newark, N. J.
Philadelphia Bronze & Brass Corp., Philadelphia, Pa.
Reynolds Metals Co., Louisville, Ky.
Scovill Manufacturing Co., Waterbury, Conn.
Steel Improvement & Forge Co., Cleveland, Ohio
Vanadium Corp. of America, New York, N. Y.
Wyman-Gordon Co., Worcester, Mass.

Materials & Methods

Materials Engineering File Facts

NUMBER 173
March, 1949

METHODS: Carburizing
MATERIALS: Steel

Comparison of Commercial Carburizing Processes

Name of Process	Carburizing Medium, and Type and Depth of Case Produced	Hardening Method	Equipment Used	Remarks
Cyanide Case Hardening	Medium: molten sodium cyanide bath. Type of case: carbon-nitrogen.[1] Operating range: 1400 to 1600 F. Time at temperature: 1 min. to 1 hr.[2] Case depths obtainable: 0.001 to 0.010 in.[2]	Work pieces can be heated individually or in trays or baskets; work can be quenched in water, brine or oil	Externally heated pots equipped with temperature controls and ventilation hoods are common; rinsing or cleaning equipment needed for the removal of salt after quenching; suitable methods for the disposal of used cyanide-containing salts must be provided as they cannot be dumped into the sewer in many cities	Generally used for very shallow cases on small parts; batch type installations are the most common; cyaniding baskets and trays have longer lives if they are not quenched with the work-pieces; oil-quenched parts must be cleaned in an alkaline cleaner; water and brine quenched parts need only a hot water rinse; quenched and washed parts require an oil dip to prevent rusting in storage
Activated Cyanide Case Hardening	Medium: molten cyanide salt plus a calcium or barium salt as a catalyst. Type of case: carbon-nitrogen.[3] Operating range: 1200 to 1675 F. Time at temperature: up to 3 hr. Case depths obtainable: up to 0.040 in.	Same as for cyaniding	Commercial installations range from small batch type pots to mechanized salt baths for use in production lines; ventilation hoods and temperature controls are needed for each pot; suitable methods for the disposal of used cyanide containing salts must be provided as they cannot be dumped into the sewer in many cities	Activated cyanide salts are slightly more difficult to remove from quenched work than are straight cyanide salts; water and brine quenched parts come clean easily; oil quenched work can be washed in hot water; when exceptional cleanliness is desired, an acid dip followed by an alkaline rinse may be needed; a carbon (graphite) cover is often maintained on top of these salt baths to retard decomposition of the salt and to reduce heat losses; periodic analyses of salts are advisable for maximum operating economy
Salt Bath Carburizing	Medium: molten salt bath containing less cyanide than above types. Type of case: carbon-nitrogen.[4] Operating range: 1650 to 1750 F. Time at temperature: up to 15 hr. Case depths obtainable: up to 0.150 to 0.160 in.	Same as for cyaniding	Externally heated or internal electrode pots are generally used; ventilation hoods and temperature controls are needed; equipment may be batch type or part of a conveyorized production line; suitable methods for the disposal of used cyanide-containing salts must be provided as they cannot be dumped into the sewer in many cities	As with other salt bath processes, small amounts of floor space are required and per-piece handling time is low (especially if parts can be heated in trays or baskets); efficiency is higher if bath is operated continuously; a carbon (graphite) cover on the salt helps to cut down losses; regular analyses and balanced additions must be made for maximum operating economy; the removal of salt from the quenched work-pieces is easy (see activated cyanide case hardening above)

(Continued on page 87)

NUMBER 173 (Continued)

COMPARISON OF COMMERCIAL CARBURIZING PROCESSES

Name of Process	Carburizing Medium, and Type and Depth of Case Produced	Hardening Method	Equipment Used	Remarks
Pack Carburizing	Medium: Workpieces are heated while packed in a powder composed largely of charcoal or coke (parts are sealed in an alloy carburizing box or pot). Type of case: carbon. Operating range: 1550 to 1750 F. Time at temperature: 3 or 4 to 48 hr. Case depths obtainable: 0.025 to 0.250 in.	Parts can be removed from carburizing boxes and direct-quenched, or they can be slow-cooled and then reheated for hardening; for maximum grain refinement in both case and core of carburized workpieces, double quenching is advisable	Simple furnaces with no atmosphere are used; temperature control must be accurate (plus or minus 10 F) and temperature variation throughout furnace should not exceed 20 F; wrought alloy boxes or containers are used; equipment for handling loaded boxes and for sifting, weighing, storing and mixing carburizing compound is required; box (batch) type fuel or electrically heated furnaces are common; for large quantities of small parts rotary retort furnaces are sometimes used; pusher-type continuous furnaces are used when volume of production is great enough	A simple, inexpensive process; the equipment is plain and fairly long lived; carburizing compound is not expensive and it is dirty to store and handle; the per-piece labor costs are often higher than with other carburizing methods as it is a hot, dirty job unless a completely mechanized installation is used; parts may be slow-cooled from the carburizing heat and stock can be removed by machining from areas that must remain soft after hardening
Gas Carburizing	Medium: Gas atmosphere rich in carbon; this is obtained by cracking an air-gas (natural or manufactured) mixture enriched with propane or methane if necessary, or by using the vapor of an easily vaporized liquid hydrocarbon. Type of case: carbon.[5] Operating range: 1550 to 1750 F. Time at temperature: 1 to 8 hr. Case depths obtainable: 0.010 to 0.060 in.	Small parts are carburized in baskets or trays; fixtures are often used for larger parts; by adjustment of the air-gas ratio input to the gas generator (or by other suitable control means) the carbon content of the case produced can be accurately regulated	Furnace must be gas-tight or have a gas-tight retort or muffle; the gas must be constantly recirculated inside the furnace for maximum efficiency, unless the work moves through the furnace or if a suitable flow of gas is maintained; accurate temperature control (plus or minus 10 F) and an even distribution of heat (temperature variation throughout furnace should not exceed 20 F) are required; furnace must be equipped with a suitable gas generator or fluid pump and control apparatus; both batch and continuous types of furnaces heated by fuel or electricity are available; pit type furnaces require an overhead crane for loading and unloading; batch type furnaces generally need an adjoining cooling chamber for slow-cooled work (to prevent scaling and to retard cooling)	A clean, easily controlled process; space requirements are somewhat greater than for salt baths; per-piece handling costs are generally low; a wide variety of jobs from carburizing through carbon-restoration to bright-hardening of previously carburized (or of high carbon or alloy steel) parts is possible in the same furnace if the equipment is engineered for this type of work; the use of a vaporizable liquid hydrocarbon as a source of carbon is generally restricted to pit (batch) type carburizing furnaces as this process is not economical for use in the larger continuous furnaces

[1] *This case is second only to a nitrided case in hardness and wear resistance.*

[2] *Greater times (to produce deeper cases) are not economical; activated salt baths are used for deeper cases.*

[3] *Low temperatures produce cases higher in nitrogen and lower in carbon content than do the higher salt bath temperatures; activated or accelerated cyanide salts produce cases having less nitrogen than do the straight cyanide salts.*

[4] *The nitrogen content is very low, usually less than 0.010%.*

[5] *Ammonia can be added to the gas to produce a carbon-nitrogen case; this process is called dry cyaniding, ni-carbing or carbo-nitriding.*

Compiled by Robert S. Burpo, Jr.

HASTELLOY
Trade-Mark
Alloy Cyaniding Equipment

Gives thousands of hours' service

HASTELLOY nickel-base alloys are being used more and more where elevated temperatures and thermal shock are combined with corrosive conditions. Cyaniding baskets and racks, for example, give months of service when made of HASTELLOY alloy sheet. For these alloys are strong, ductile materials that resist the effects of extreme heat and repeated quenching, as well as the corrosive action of molten cyanide.

If your operating conditions demand a metal that will resist scaling and corrosion and maintain high mechanical strength at elevated temperatures, one of the four grades of HASTELLOY alloy may solve your problem. These alloys are available in all standard forms and can be readily fabricated by most common methods. For descriptive literature and price lists, contact our nearest district office.

PART: Cyaniding Basket
ALLOY: "HASTELLOY" A
BATH TEMPERATURE: 1550 deg. F.
COOLING: By dumping in water
LIFE: 3 years

PART: Cyaniding Rack
ALLOY: "HASTELLOY" A
BATH TEMPERATURE: 1625 deg. F.
COOLING: In oil
LIFE: 1 year

HAYNES
TRADE-MARK
Alloys

Haynes Stellite Company
Unit of Union Carbide and Carbon Corporation
UCC
General Offices and Works, Kokomo, Indiana
Sales Offices
Chicago—Cleveland—Detroit—Houston
Los Angeles—New York—San Francisco—Tulsa

The trade-marks "Haynes" and "Hastelloy" distinguish products of Haynes Stellite Company.

MATERIALS & METHODS DIGEST

A selective condensation of articles — presenting new developments and ideas in materials and their processing — from foreign journals and domestic publications of specialized circulation.

Edited by H. R. CLAUSER

Cold Pressure Welding of Light Alloy Sheet

Cold pressure welding of light alloys is eceiving considerable attention in England ecause it offers a rapid and economical ethod of joining. In November 1948, MATERIALS & METHODS published a detailed account of this process; and in October, a technical report on the process by R. F. Tylecote appeared in *Transactions of the Institute of Welding* (British).

The size of the welded specimen, it was ound, affected the apparent shear stress markedly. When allowance was made for this, the strength of a pressure weld was about the same as that of a spot weld. High purity aluminum was welded successfully between rollers at room temperature. This type of cold welding might well be extended o alloys with other forms of tools. A substantial improvement can be obtained by solution heat treatment of welds made with small reductions in sheet thickness in clad duraluminum type alloys. This was due to the strengthening of the low strength cladding by diffusion of the core constituents. Corrosion tests in salt spray and nitric acid indicated no preferential attack of pressure welds.

An improved preparation of the surface by scratch brushing increased the strength of welds in the aluminum containing 3.5 and 7% magnesium, but there was still a characteristic difficulty in preparing these alloys for pressure welding. An attempt to improve their weldability by interposing a magnesium foil showed no material advantage. In most of the tests, the time between scratch brushing and welding was as short as possible. Much longer times, however, might be unavoidable under industrial conditions, so this variable was investigated.

It was concluded that the time of exposure at room temperature between cleaning and welding must be very short for good pressure welding of aluminum and the aluminum-7% magnesium alloy. On the other hand, the aluminum-3% magnesium and the aluminum-magnesium-silicon alloys will pressure weld satisfactorily after many hours of such exposure. Short exposures at temperatures up to 750 F gave similar results.

An electrical "projection welding" machine was shown to be effective on aluminum and aluminum-manganese. Collapsible aluminum tubes pressure welded in this way met specification requirements. Tests on welding aluminum to magnesium indicated that magnesium alloys could be clad with aluminum or aluminum-3.5% magnesium, if desired. The resulting products should be easier to pressure weld than the base material.

New Finishes and Coatings for Light Metals

Hard Chromium Plating of Light Alloys

Hard chromium plating was originally confined to ferrous alloys, but in recent years its use has extended to the aluminum alloys. Some practical hints on the chromium plating of aluminum are given by J. Patrie in the Nov. 1948 issue of *Revue de l'Aluminium* (French).

Spalling and poor wear resistance of the chromium plate were found when it was deposited on an intermediate layer of nickel. Since the other metals that could be used for intermediate deposits were too soft to support relatively thick layers of chromium, a method of plating the chromium directly on the aluminum was developed. The best results were obtained when the aluminum was chemically roughened prior to plating.

Two pickles, used at temperatures slightly above room temperature, gave satisfactory roughening: one with nickel chloride, hydrofluoric acid and boric acid; the other with manganese sulfate and hydrochloric acid. The first is recommended for aluminum as well as its alloys with magnesium or magnesium and silicon. The second solution is not as good for the cast alloys of these types, but is better for wrought alloys. Neither is satisfactory for duraluminum. Sand cast alloys, as well as permanent mold or die cast alloys, cannot be chemically roughened.

After the pickling or roughening operation, the aluminum was covered with a thin layer of nickel or manganese, which had to be removed by a dip in a suitable solution prior to plating. With this procedure, it was necessary to modify the usual hard chromium plating solutions by reducing the sulfuric acid content.

A comprehensive investigation has not yet been made of the corrosion resistance of chromium plated aluminum. It is remarkably good, however, in alkaline solutions despite the porosity of the chromium. This is believed to be due in part to the well known inhibiting action of chromium on the corrosion of aluminum, and in part to the absence of a more electropositive intermediate layer such as copper.

Spraying Light Metals with Steel

An innovation in the rapidly expanding field of metallizing is the spraying of aluminum and magnesium with steel. A group consisting of representatives of the aluminum, magnesium, welding and metallizing industries in France, and delegates from various French governmental departments, have been exploring this subject. The practical conclusions reached are outlined briefly in *Revue de l'Aluminium* (French), Nov. 1948.

Aluminum and magnesium alloys can be sprayed with steels ranging from low to high carbon grades as well as with the 13% chromium and the 18 chromium, 8% nickel types. The adherence of the sprayed deposit is strictly mechanical and is not the result of alloying. The deposit is harder than the original steel used for spraying. Because of its porosity, the deposit has interesting self-lubricating and anti-seizing properties. Its coefficient of friction is less than that of rolled steel.

In spite of the porosity, deposits over

DIGEST

about 0.04 in. thick are considered to be water-tight and an electrolytic couple with the base alloy is not to be expected. If only part of the light alloy is sprayed with steel, then the potential electrolytic couple should be neutralized by a strip of sprayed zinc. Mild steel deposits can be machined with high-speed steel tools, using the same angles as for cast iron; but deposits with 0.6% carbon have to be machined with carbide tools.

The advantage of this process is the increase in the wear resistance of aluminum and magnesium alloys to a value comparable to that of steel. Therefore, this practice is expected to be important in applications where light weight is essential and where aluminum and magnesium otherwise could not be used because of their inadequate wear resistance.

Protection of Aluminum by Gelatine Films

The use of chromates and bichromates for the passivation of various metals is well known. The disadvantages of some of the previous methods of applying chromates and the advantages of a new procedure are pointed out by J. Frasch in the Nov. 1948 issue of *Métaux & Corrosion* (French).

Many of the disadvantages of the former methods appear to be overcome in the new "Framalite" process. This process is based on the use of zinc or manganese bichromate in a gelatine solution. The concentration of the gelatine and bichromate in the solution before application is such as to give a stable solution. The pH must be kept within the limits of 4 and 5.2. After the gelatine solution is applied to the metal, the evaporation of the water solvent changes the concentration of the gelatine and bichromate so as to cause the gelatine to become insoluble in water. Therefore, a chromate-containing insoluble film is formed which protects the metal against corrosion.

Bichromates are preferred to chromates because more can be incorporated in the solution without making it unstable. Zinc and manganese bichromates give better results than sodium and potassium bichromates, both from the standpoint of the time required for the gelatine to become insoluble and the corrosion resistance of the resultant film.

The Framalite process is being used commercially in France. The solution may be applied by dipping, or with a spray gun, sponge or brush. The surface to be coated should be clean and grease-free. Since no reaction with the metal is involved, only a thin layer is required. After about 15 to 45 min., the film is dry to the touch, but 48 hr. at room temperature or 10 to 15 min. at 210 to 230 F are needed for the gelatine to become completely insoluble.

The pale yellow film is so thin that the size of parts is not increased significantly.

DIGEST

The film is very adherent, so the coated parts may be subsequently formed. Parts coated by this process may be dyed or painted. The corrosion resistance of coated parts is excellent; in the case of aluminum, Iramalite gives a resistance at least as good as that of anodically treated metal and considerably superior to that of other chemical processes. It is suitable for all kinds of metals and, therefore, can be applied to equipment containing more than one metal to avoid electrochemical corrosion.

● Creep measurement of test specimens by means of SR-4 bonded resistance wire strain gages instead of the conventional extensometer is reported by C. H. Betts of the *Canadian Bureau of Mines*. He states that this method is simple, accurate and sensitive, and avoids the problem of attaching cumbersome and inconvenient mechanical devices to test specimens. Gages can be applied to more than one point, if desired, or they may permit using specimens of more convenient dimensions in some instances. The investigation was limited to measurement at room temperature.

Temper Brittleness in Plain Carbon Steels

It has been almost universally accepted that plain carbon steels are not susceptible to temper brittleness and that alloying elements introduce temper brittleness. In *Metals Technology*, Dec. 1948, L. D. Jaffe and D. C. Buffum set forth a directly opposite view. They support the possibility that plain carbon steels are not only susceptible to temper brittleness but are much more susceptible than alloy steels, in the sense that they embrittle much more rapidly. The previous views, with which they disagree, they believe are based upon an erroneous interpretation of experimental results.

The criterion to which the authors refer involved notched-bar impact tests only at room temperature, whereas the criterion now generally used retains the same heat treatments, but the impact tests are made over a range of temperatures, covering the transition from ductile to brittle fracture. Based on their limited tests in accordance with the latter criterion, they arrived at three conclusions: (1) Plain carbon steels are susceptible to temper brittleness; (2) temper brittleness develops so rapidly that even drastic quenching from a high tempering temperature is insufficient to suppress it; (3) alloying elements retard the rate of development of temper brittleness.

DIGEST

A New Pre-Enamelling Treatment for Steel

Because of the shortage of enamelling steel, many enamellers have been forced to use other grades of steel, which give a much higher percentage of rejects. The rejections caused by defects such as reboiling, blistering and copperheads can be greatly reduced by the use of "nitralising" a pre-enamelling treatment described by T. Gilbertson and R. Robinson in *Sheet Metal Industries* (English), Nov., 48. Pickling for long periods may improve the enamelling properties in some cases, but it is not, by itself, a satisfactory pre-treatment.

The nitralising treatment consists of degreasing and acid pickling the metal and then immersing it in fused sodium nitrate at about 930 F. The period of immersion depends on the particular material being treated. On removal, the metal is cooled and rinsed in water, after which it is pickled for a few minutes and again rinsed. The final pickle or dip is the normal one used in vitreous enamelling.

The favorable results are believed due to the fact that at high temperatures the nitrates combine with carbon and sulfur. Therefore, the smut formed during pickling is burnt up, as are any residues of soaps, slurries or plain dirt. Occluded hydrogen from pickling is entirely eliminated, and the "blueing" of the metal is removed in a few minutes in an acid pickle. The material should be as clean and grease-free as possible before treatment in the nitrate bath, as the rapid oxidation of any large quantity of organic material introduced into the fused salt would be highly dangerous.

Fabricating Stresses in Metals

Recently two engineers, one in the automotive field and the other in the aircraft field, had some pertinent things to say about stresses set up in metals during fabrication. O. A. Wheelon, in a paper presented before the *Society of Automotive Engineers*, pointed out that the old criteria of ultimate tensile strength, yield strength, and elongation in 2 in. are no longer of much value. A full range stress-strain diagram is needed to know something of the material's work hardening characteristics and the critical necking strain in simple tension.

The local elongation at fracture must also be known since it is the criterion which governs many of our fabrication operations, such as dimpling and bending. He also pointed out that current design trends in materials are causing production complica-

DIGEST

ons since the physical properties as well s the residual stress pattern is highly de-endent upon the fabrication techniques mployed. Residual stresses may have an ffect upon fatigue and have a pronounced ffect upon warpage if any material is re-oved by subsequent drilling, machining, r scarfing that will disturb the residual ress system.

These residual stresses can often be used o advantage, as was explained by R. Schil-ing before the *Engineer's Club of St. Louis.* ome types of heat treating or mechanical rocesses, such as cold hammering, surface olling, presetting or shot peening, can make ard, brittle materials superior for severe rvice by protecting the surfaces with apped compressive stress.

With ductile material having the proper apped stresses, parts under repeated load-g have a much longer life than parts at have either none or improper type of apped stresses. Prestressing is a method f controlling trapped stresses so that the rvice life of the part is improved. While apped stresses which are in the same direc-on as service stresses will be additive and rhaps cause failure, trapped stresses which e in the opposite direction will reduce e total stress in service and hence are eneficial.

Low Alloy Steel vs. Carbon Steel for Wires

In these days of steel shortages, any eight saving possibilities are more than elcome. In the *Journal of the Iron & teel Institute* (English), Nov., 1948, J. C. udson points out the saving in materials d the reduced costs of replacement that n result from the substitution of low alloy eel wire for unalloyed wire in applications volving atmospheric corrosion.

Ten-year corrosion tests in an industrial mosphere were made on a number of rrous materials, including carbon steels, alloyed wrought irons, various low alloy eels containing small percentages of copper d, in some cases, chromium, and copper-aring wrought irons. The rate of corro-on did not vary appreciably with duration f exposure, but was affected by the di-meter of the wire, being greater for thin an for thick wires. Certain wrought ons, including both the copper-bearing d some of the unalloyed wrought irons, d the low alloy steels proved much more sistant than mild steel.

The most favorable results were obtained ith the low alloy steels containing about 25 carbon, 0.8 manganese, 0.6 to 0.9

DIGEST

chromium and 0.5% copper. The average economy in weight resulting from the substitution of chromium-copper steel for mild steel would be of the order of 50%. The cost of the alloying elements would, of course, have to be set off against the saving that would result from the use of the low alloy steel.

In all probability, however, the maximum long term economies resulting from the use of low alloy steel wires would be achieved by maintaining the present wire gages and thus reaping the benefits of the increased life of the fabricated articles, for the cost of the materials themselves is but a small fraction of the expense involved in replacement at unnecessarily short intervals.

● German manufacturers of aircraft tools found an unusual variety of uses for compressed impregnated wood, methyl-methacrylate and phenolic sheet materials, but they scarcely used phenolic and cellulosic casting resins for aircraft tools, according to a report from the *Office of Technical Services, Dept. of Commerce.* Silver vapor coating of plastic windows for aircraft was used to reduce searchlight glare in night flying and the process, adapted to other metals, was considered for use as a hard protective coating for plastic surfaces, or as an electrically conducting layer for defrosting.

Bright Future for Fluorine-Containing Plastics

The development and widespread availability of cheap fluorine-containing plastics combining thermal and chemical stability at high temperatures can be anticipated, according to Dr. G. Gavlin, writing in *The Frontier,* Dec. 1948. Prewar exploratory work and intensive studies in the field carried out in conjunction with the Manhattan project promise this.

The nature of fluorine compounds is already widely recognized. They are nontoxic, nonflammable, and exhibit satisfactory corrosion characteristics toward iron, steel, aluminum, copper, Monel, tin, and tin solders at 347 F.

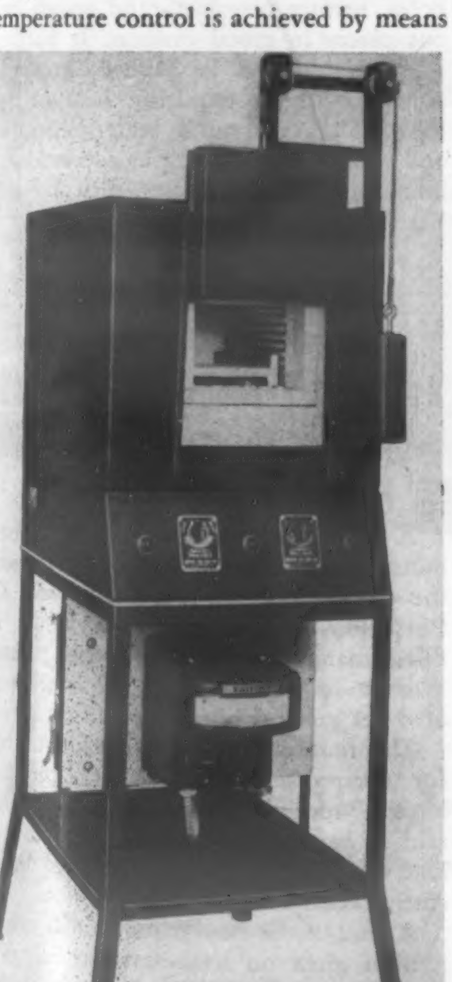
Perhaps the best known fluorine-containing plastic is Teflon, which is highly stable to heat and oxidation. It can withstand temperatures of over 300 F. The electrical properties are also good. However, the cost is high and they are very difficult to work. Another highly stable recently developed

New Materials and Equipment

Electric Furnace Has Accurate Temperature Control

A new floor model electric furnace designed to give close temperature control has been introduced by the *K. H. Huppert Co.*, 6830 Cottage Grove Ave., Chicago. Designed specifically for tool and die work, hardening and drawing, the new furnace affords practical heat control over the range from room temperature up to and including 2000 F.

Temperature control is achieved by means of step-less input controllers mounted onto the base of the furnace, and another control mounted beneath the furnace itself; all controllers are thus integral parts of the unit.



Having a temperature range from 100 to 2000 F, this Huppert furnace is suitable for hardening and drawing.

This furnace has two sets of heating elements. The top and bottom comprise one set, with the two sides making up the other element. Each set is controlled by one of the step-less input controllers with the temperature governed automatically by the third control, called a Capacitrol. With this unit it is possible to control temperatures as low as 100 F with the same accuracy as higher temperatures are controlled in ordinary furnaces.

For drawing purposes, requiring temperatures of 350 to 500 F, both sets of elements can be placed in low position on the input controllers, with the Capacitrol providing uniformity of temperature. For steel hardening, the furnace operates over the normal range of 1400 to 2000 F.

Inside dimensions of this furnace are 8 in. wide, 6 in. high and 12 in. deep. Overall dimensions are 24 in. wide, 29 in. deep and 68 in. high.

Printed Circuits Made by Three Different Methods

Three processes for producing "printed circuits" on electrical, electronic and optical parts, all based on fine definition photography, have been announced by the *Kenyon Instrument Co.*, Huntington Station, L. I., N. Y. Electrically conductive or resistive patterns with a dimensional accuracy of 0.0002 in. are said to be possible for miniature electronic tubes, switching circuits, continuously tapered resistance pots, and inductance coils.

In one of the processes, a photographic image is formed on a light-sensitive emulsion; the gelatinous image is transferred to the chosen base material; and the image is dissolved and replaced by any desired material that can be obtained in powdered form. If a conductive pattern is required, only the noble metals or carbon may be used. A wide choice of base materials is possible, but the thermosetting and thermoplastic resins are most useful.

In another process, the photographic image is used as a mask in a special electroplating technique, and the plated metal image is transferred to the chosen base. By this process, patterns may be formed only with the metals that are readily electroplated, but a wide choice in base material is available. Results of this process are characterized by a high order of surface smoothness because the pattern is inlaid into the base.

In the third process, an exceedingly fine grained ultra-violet sensitive silver-halide emulsion is the starting point. This emulsion is applied to the surface upon which a conductive pattern is to appear. A variety of ceramic materials may be used as the base, but because of the severity of the physical and chemical treatment necessary in the subsequent phases of the process, plastic materials cannot be used.

• Development of additional temperature ratings in their temperature indicating products has been announced by the *Tempil Corp.*, 132 West 22 St., New York 11. All three types—crayons, liquid, and pellets—are available in 12.5 F intervals from 113 to 400 F. From 400 to 1600 F, the crayons and liquid are available in 50 F increments, while the pellets can be had up to 1700 F.

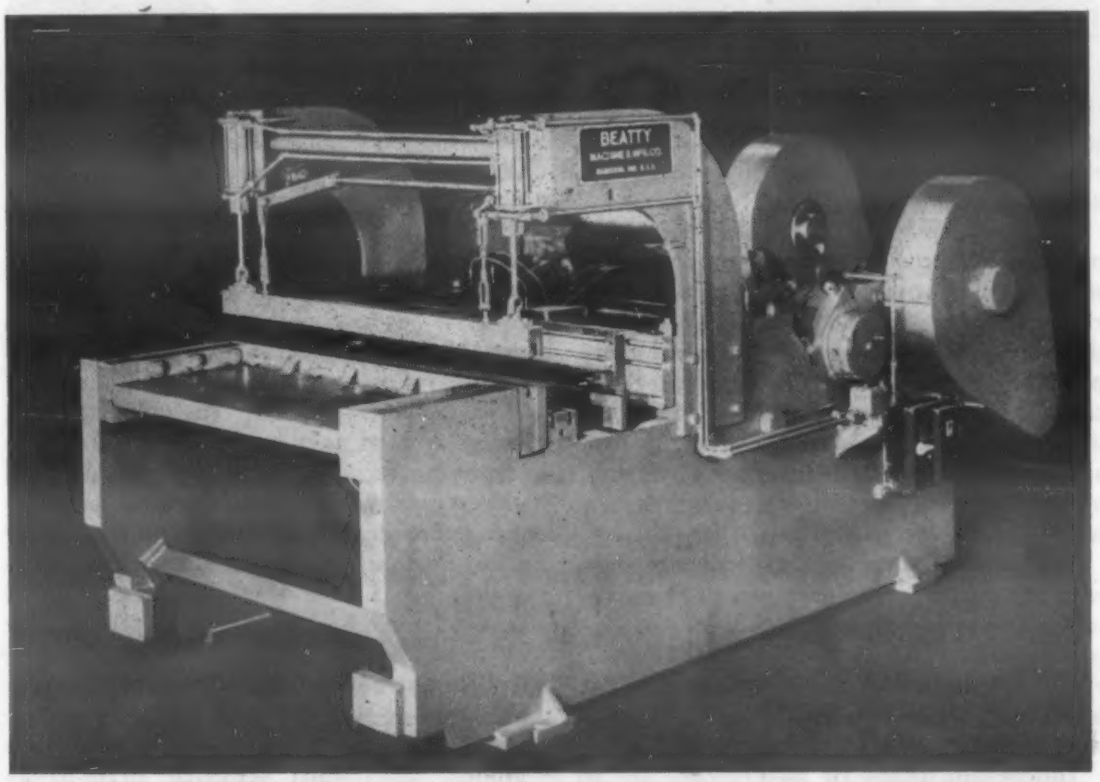
New Materials and Equipment
(CONTINUED)

Machine Designed for Multiple Punching of Flanges

A horizontal multiple punch has been developed by the *Beatty Machine & Manufacturing Co.,* Hammond, Ind. The machine is designed for multiple punching the flanges of long, wide sheets, and allows for punch tools to be mounted on varying centers across the ram face. The machine is fitted with an air clamp device which holds the material down during the punching operation for gaging purposes.

Stripping is accomplished by air cylinders, which travel with the ram. The frames are of welded steel plate. Clutches are of the jaw type with motor drive V-belt to flywheel.

The new machine is available in capacities from 50 to 300 tons. On the 200-ton machine, the distance between housings is 63 in., the stroke is 6 in., and the stroke per minute is 28 in.



This new Beatty horizontal multiple punch is produced in capacities from 50 to 300 tons.

Fused Metal Coatings Give Added Surface Protection

This process of applying coating metals to base metals, developed by the *Fusion Metal Coating Co.,* 21820 W. Eight Mile Rd., Detroit, provides a protective surface against wear, corrosion and oxidation.

The Fusecoat process is a system for applying a fused layer of coating metal to a base metal. Both the coating metal and the base metal can be either a pure metal or an alloy. They can both be either ferrous or nonferrous. The base metal must have a higher melting point than the coating metal, or, as in the application of refractory coatings, a higher melting point than the binder metal.

The thickness of coating applied is under control and ranges from 0.0005 in. to 0.020 in., depending upon requirements in each application. Contours can be coated, including inside diameter surfaces. The coating can be applied to any desired area with the uncoated area of the base metal protected from oxidation during the fusing operation.

Refractory coatings, with lower melting point metals serving as binder metals, can be applied to give highest possible abrasive resistance to the coated area. The refractory particles, of controlled concentration, can be made to protrude any desired distance beyond the binder metal, or, if desired, the two metals can be made flush with the refractory particles.

If protection is desired just for corrosion, only a very thin smooth layer is required. A part may be given a heavy coating in one spot for protection against combined wear and corrosion, and a thin coating in another area for resistance to corrosion only. Both areas can be heated at the same time.

Heating, which is necessary to obtain a fusion bond between the two metals, can be by furnace or induction, but the preferred method, in most cases, is by a liquid bath developed especially for the process.

● Applied with an ordinary putty knife, a free spreading cold solder produced by *Alvin Products, Inc.,* 20-22 Houghton St., Worcester 4, Mass., fills blow holes, sand holes, surface blemishes and rough or porous places in metal castings. It hardens in minutes and can be sanded, ground and painted without requiring heat or special tools. The compound seals joints, cracks and gaskets, and fills cracks and solders over bumps, rope welds, holes, pits and gouges.

Low-Cost Phenolic Molding Powders Developed for General Purpose Applications

A new group of general purpose phenolic molding powders has been developed by the *General Electric Co.'s Chemical Dept.,* Pittsfield, Mass. These new wood flour-filled materials are said to be priced an average 1¢ per lb. below the market price of other general purpose molding powders.

The four compounds—black and brown for compression and transfer molding—have a specific gravity of 1.37, and are said to have flow characteristics, cure time, and water resistance nearly equal to more costly wood flour-filled phenolics.

Although the new materials do not have a high gloss on long-draw moldings and may show a slightly less rigid discharge from the mold, tests by the company indicate that they are satisfactory for the majority of thermosetting plastics applications.

New Materials and Equipment

Plastic Handle Features New Design

The development of a new improved handle for vacuum-type coffee makers has been announced by the *Consolidated Molded Products Corp.*, 309 Cherry St., Scranton 2, Pa.

This coffee maker handle has unique thumb rest design.

The handle is molded of phenolic plastic with asbestos-filled, heat resistant, high impact strength qualities, and features a double thumb rest on top the handle arch to permit a balanced grasp by either right or left hand.

Tape Protects Steel Against Scratches During Fabrication

Production of protective tape designed to protect stainless steel against die marks and other scratches during fabrication has been announced by the *Minnesota Mining & Manufacturing Co.*, 900 Fauquier St., St. Paul, Minn.

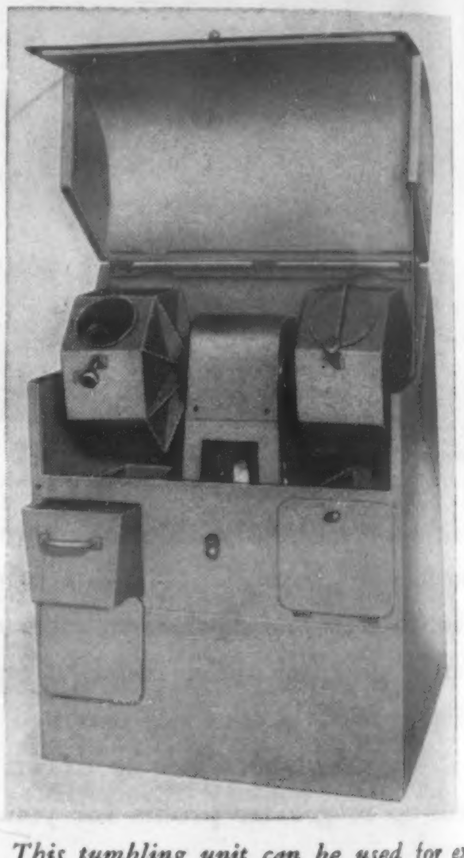
It is applied directly from the roll to the entire metal surface prior to fabrication, and may be left in place through packaging, shipping and storing of the finished product. The tape comes in 100-yd. rolls, 36½ in. wide, with narrower widths available. Thickness is 0.006 in.

Protection for the steel surface is afforded by the tape's specially-designed adhesive, which constitutes a continuous film that stretches with the metal during fabrication. Patterns can be traced on the tape's flat paper backing.

New Materials and Equipment

Tumbling Unit Designed for Small Parts

A mechanical deburring and finishing unit, Model DBO-1, for small parts or for small production runs has been introduced by the *Almco Div., Queen Stove Works, Inc.,* Albert Lea, Minn. It is also suggested for use in experimental deburring and finishing. It is equipped with safety switch, switch box and ½-h.p. electric motor (220



This tumbling unit can be used for experimental deburring and finishing as well as for small production run.

to 440 v., 60 cycle, 3 phase, 1750 r.p.m.) New features include variable speeds from 35 to 70 r.p.m., which can be changed while machine is in operation, all welded steel construction with removable unloading drawers with drain and removable screen, and quick-opening and closing water-tight doors.

Injection Molding Equipment for Plastics

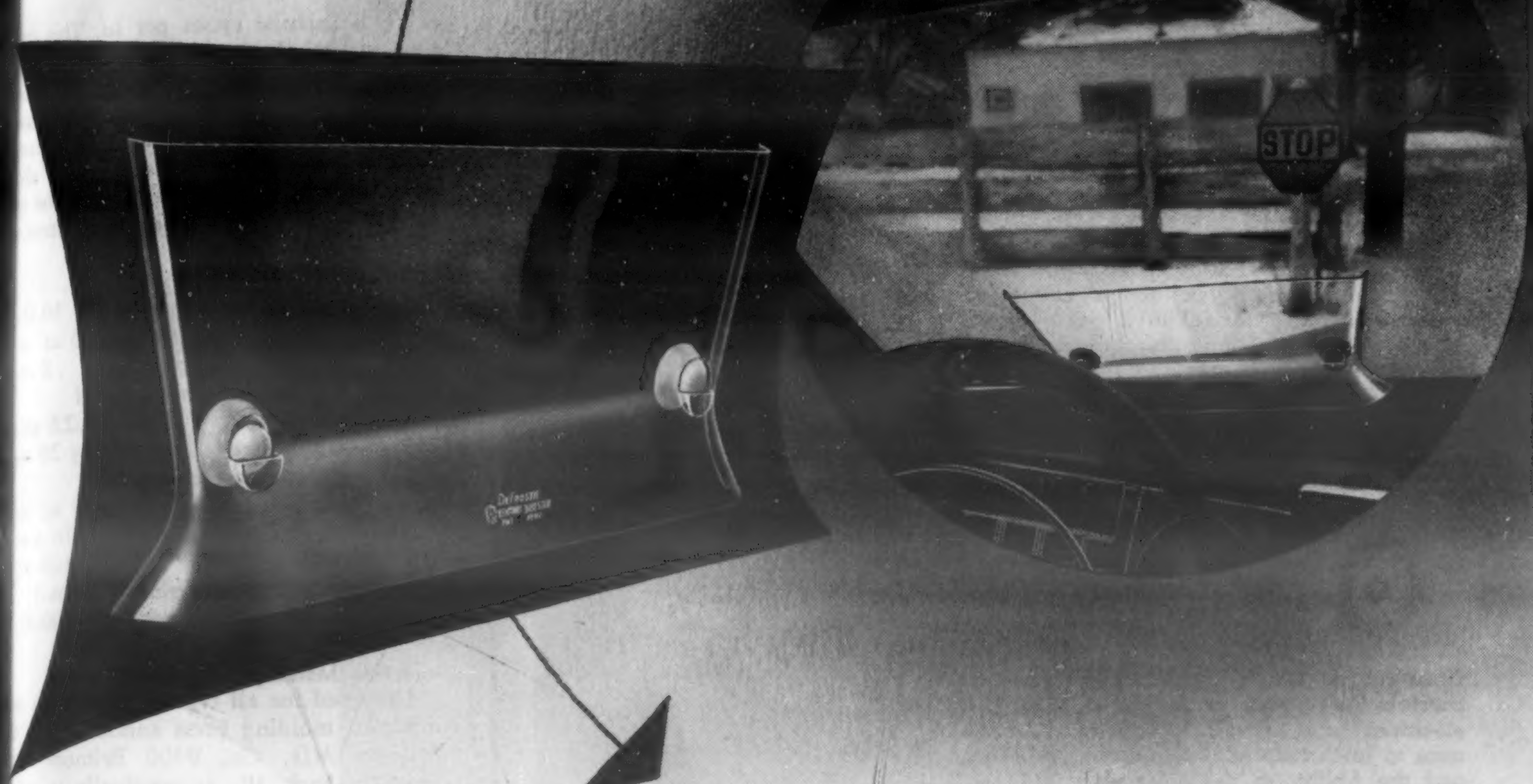
4-Oz. Injection Molding Machine

This new 4-oz. injection molding machine introduced by *Lester-Phoenix, Inc.,* 2711 Church Ave., Cleveland, has a speed

Clear Winter Windshields

with

De Frosties



DEFROSTIE, *held in place by two rubber suction cups, is easy to install or remove. DeFrosties fit all cars. Sold by gas stations and accessory stores. Manufactured for Peters and Russell, Inc., Springfield, Ohio.*

ANOTHER MACOID-MADE PRODUCT

THE IDEA: To concentrate warm, defrosting air on the windshield, thus clearing it quickly.

THE PROBLEMS: To accomplish this without hindering driver's vision . . . make design blend with windshield . . . attach securely to windshield.

THE RESULT: Macoid selected proper transparent material so that vision not impaired . . . engineered and produced molds . . . planned and set-up production . . . assembled parts . . . boxed whole unit. Now produces and ships many DeFrosties.

LET MACOID'S combined facilities of designing, engineering, and production be of service to you. At no obligation, a Macoid representative will discuss plastic application to your product.

SOCIETY OF THE PLASTICS INDUSTRY · SPI

Originators of Dry Process Plastics Extrusion

DETROIT MACOID CORPORATION

Extrusion and Injection Molding • 12342 CLOVERDALE, DETROIT 4, MICH.

New Materials and Equipment

of 600 machine cycles per hr. This spe can be partially attributed to the high pl ticizing capacity of the internally hea cylinder. The machine applies a pressu of 20,000 psi., and is standard for Nylon.

The machine has a maximum of abo 180 shots per hr., and varies with the ty of product. A partial list of its specificatio is given below:

Plasticized material per hr.	50 lb.
Area of injection plunger	2.23 sq. in.
Stroke of injection plunger	8 in.
Time to complete injection of max. casting	2.6 sec.
Size of die plate	18 by 20 in.
Max. casting area in mold at 16,000 psi.	12 sq. in.
Mold closing pressure	70 tons
Floor space	25 by 100 in.
Total weight of machine (approx.)	6800 lb.

Injection Molding Press with Lever

Designed for all types of plastics, a ne injection molding press announced by th *Munton Mfg. Co.,* 9400 Belmont Ave Franklin Park, Ill., is specifically suited machine molding of Nylon. It handles th difficult material by using a lever to c off the sprue, which eliminates seepag screens and gadgets. The lever is not us with regular plastics.

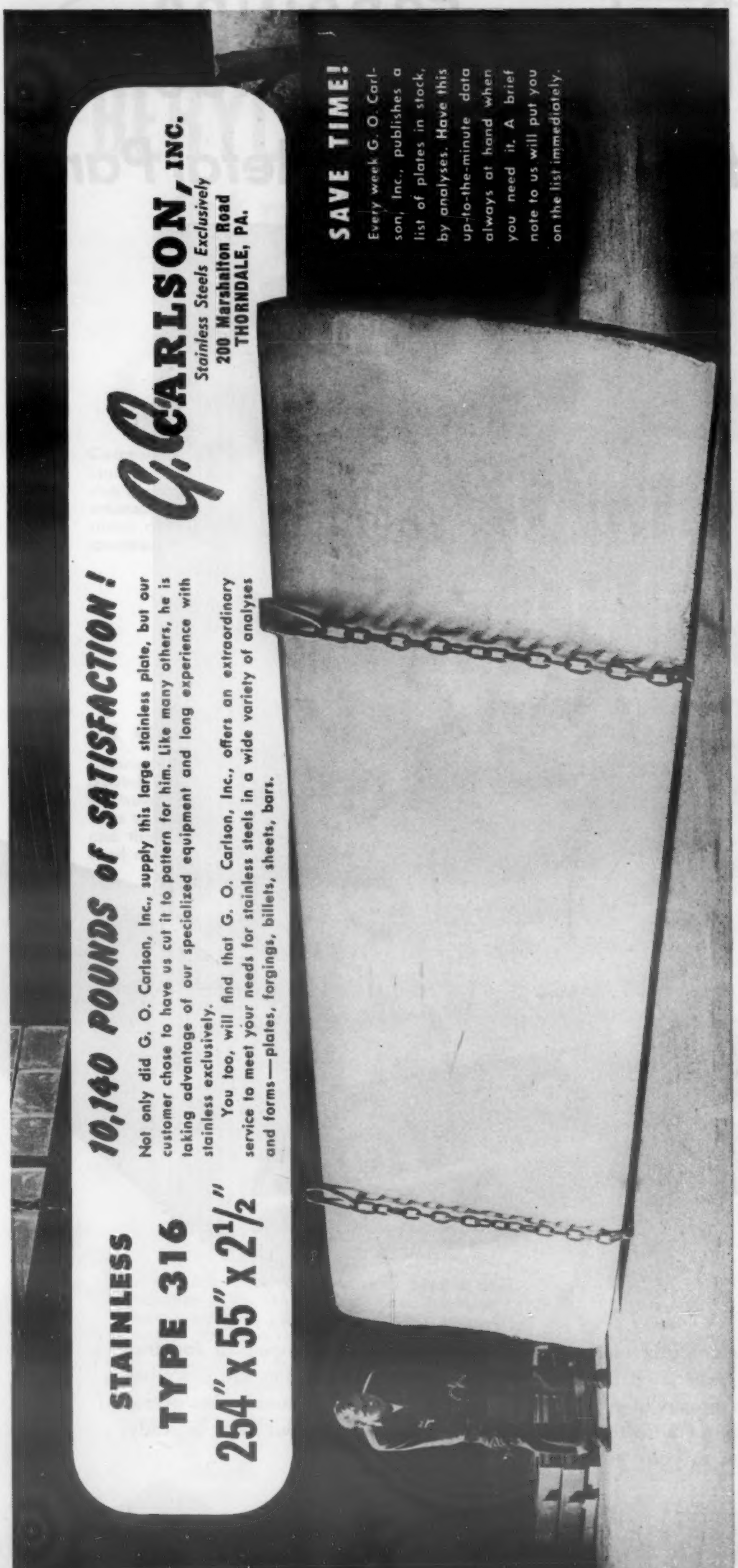
A new type heating tube plasticizes abo 20 lb. of plastic per hr. This tube is chro mium plated on the inside and does not us the conventional type torpedo. Band heate and cartridge heaters can be checked an changed from outside the tube. A speci dual heat control permits the upper part the heating tube to be set 75 to 100 F coo er than the bottom of tube. The plunger ti raises out of the heating tube so that it h time to be air cooled between shots.

The press is equipped with a 5-h.p., 220 440 v. motor and a belt driven, 6-cylind hydraulic pump. Other features include auxiliary mounting plates for top and bo tom platens, adjustable stops for openin platens, and adjustable knock out pins. Th press develops 30-ton mold clamping pre sure adjustable with a maximum of 14,00 lb. injection pressure.

Timer for Molding Machines

Injection molders concerned with addin the advantage of a stuffer circuit to thei present controls will be interested in th new packaged unit now offered by th *Watson-Stillman Co.,* Roselle, N. J., for in stallation on its Models 12E and 16E in jection molding machines.

The unit mounts on the machine bas directly above the present control cabine It consists of a 14-gage steel cabinet wit



New Materials and Equipment

grey wrinkle finish which houses all instruments for the six timer controls. A selector switch on the cabinet permits operation of machine either with or without stuffer control.

Electric Impact Hammer Delivers One-Ton Impact

A new high-speed model has been added to the present line of punches manufactured by *Black & Webster, Inc.*, Needham, Mass. This new model, BS 1, incorporates a high temperature silicone insulated coil in a solenoid which permits it to operate continuously at better than 150 cycles or blows

Metals and plastics can be fabricated with this high-speed electric punch.

per min., delivering an impact of more than a ton.

The punch is suitable for staking, riveting, marking, wire cutting, blanking, forming and drawing of metals, plastics, fabrics, leather, etc., but is particularly designed for high speed operation.

The unit weighs 45 lb. and needs less than 1 sq. ft. of bench space. This electric impact hammer lends itself to many uses where speed and high production rates are important in the field of automatic, semi-automatic or manual operation.

Celanese Offers ...EXTRUDED ACETATE SHEETING...IN VOLUME...

IN ROLLS . . . SHEETS . . . ALL THICKNESSES. Now, extruded sheeting in quantity . . . in three standard widths, slit-to-width reels and a wide selection of standard size sheets . . . supplied *with* or *without* special surface polishing. Produced in all thicknesses from .003" up.

TRANSPARENT . . . COLORS. Celanese* extruded sheeting is available in crystal transparent and in transparent, translucent and opaque colors. Configurations such as mottles, pearls and shells are being developed. Its physical characteristics equal or exceed those of the old solvent or block type sheets.

NEW LOW COST. Celanese extruded acetate sheeting sells for less than either cellulose acetate or cellulose nitrate sheets made by the old solvent or block method. Substantial savings are possible. In addition, since sheets can be supplied in a variety of widths and lengths, cutting waste is greatly reduced.

REPLACE CELLULOSE NITRATE. Investigate the possibility of replacing nitrate with this economical Celanese extruded acetate sheeting. Cellulose acetate is rated non-hazardous by Underwriters' Laboratories. It creates no storage problems and permits lower insurance rates. A better product at lower cost is possible in most cases.

As originators and producers of plastic sheets, since 1872, Celanese recommends this new sheeting as a low cost, non-hazardous, high quality material—suitable for a wide variety of applications. For complete information get in touch with your Celanese representative at your nearest district office. Celanese Corporation of America, Plastics Division, Dept. D-4, 180 Madison Avenue, New York 16, N. Y.

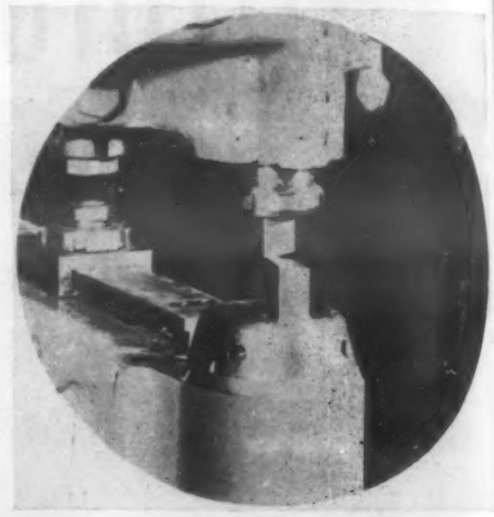
*Reg. U. S. Pat. Off.

New Materials and Equipment

Sheet and Plate Cutting Machine Has Quick-Locking Centering Device

A new machine that does beading, folding, and straight, circular or design cutting of metal up to 3/8-in. thickness has been introduced by ***Pullmax Co.,*** 5222 North Spaulding Ave., Chicago 25.

The cutting is accomplished by two cutting tools, the upper one operating at a



Close-up shows how cutting is accomplished on this sheet and plate cutting machine.

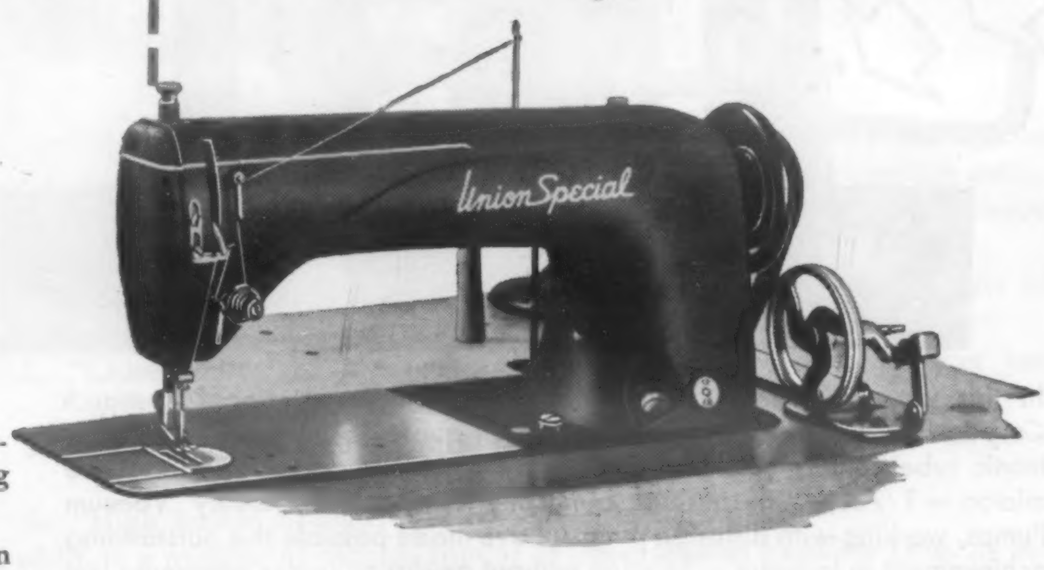
very high r.p.m. It is said not to chip or deform the metal being worked, and finished edges are smooth and perpendicular. Cutting tools do not penetrate the metal, but shear the metal to the breaking point.

Mild and stainless steel as well as all nonferrous metal can be cut into intricate designs with this cutting machine. A centering device permits fast production of circular plates. A variety of tools may be used for many special operations, such as slot cutting, nibbling, beading, and folding.

Seven sizes are available for working various gages of metal. The machines are manufactured by the Haldex Co. of Halmstad, Sweden.

● The *Hy-Pro Tool Co.,* New Bedford, Mass., has developed a multi-fluted tap that will thread holes in all plastic materials. The new plastics tap has been tested in plastics that are hard and soft and with either cloth or glass fillers. The new plastics tap has a multi-fluted design for fast chip disposal, specific modifications in cutting angles for each type of plastic to be threaded, and a surface treatment to assure proper lubrication regardless of material.

THEY CUT COSTS in more ways than one...



in this sewing machine

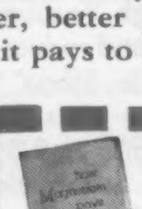
Multiple savings were achieved with magnesium in this high speed industrial sewing machine.

Of first importance was efficiency in machine operation. A magnesium die casting was employed in the needle thread take-up . . . a part which makes as high as 10,000 reversals per minute. Magnesium cut the weight of this part considerably; thus reducing starting inertia and vibration. Maintenance and replacement expenses were reduced, too, because magnesium castings possess high strength and excellent fatigue resistance.

Worthwhile savings were also realized because magnesium is economically die cast to extremely close tolerances—requires a minimum of finish machining.

Two other outstanding advantages of magnesium point the way to uninterrupted production at low cost . . . *magnesium is readily available and priced more favorably than ever before.* For all these reasons, we believe that magnesium is the inevitable metal for many, many products—that for lighter, better products to meet competition, it pays to use magnesium.

Magnesium Pays



Write for this revealing free book "How Magnesium Pays". It's filled with actual case studies of how manufacturers of a wide range of products have found that magnesium pays.

Send me the study MP 49-33 "How Magnesium Pays."

NAME __________

TITLE __________

FIRM __________

ADDRESS __________

MAGNESIUM DIVISION • THE DOW CHEMICAL COMPANY • MIDLAND, MICHIGAN

New York • Boston • Philadelphia • Washington • Cleveland • Detroit • Chicago • St. Louis • Houston • San Francisco • Los Angeles • Seattle • Dow Chemical of Canada, Limited, Toronto, Canada

New Materials and Equipment

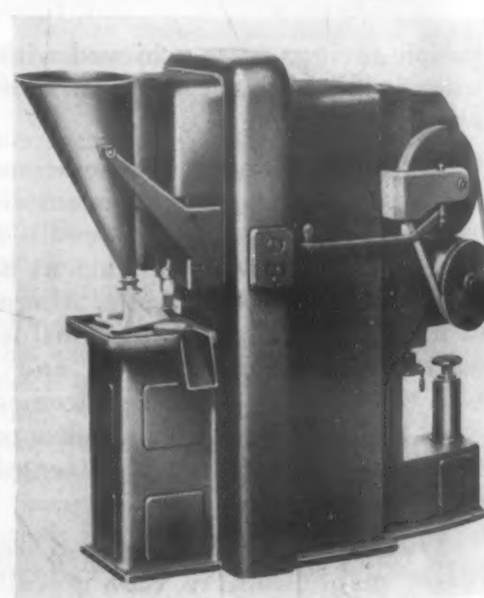
Preforming Press Suitable for Metallic and Nonmetallic Powers

A new 55-ton preforming press for preforming and molding plastics, powdered metals, generator brushes made from carbon and copper mixtures, and ceramic products, has been introduced by the *Arthur Colton Co.*, 2600 E. Jefferson Ave., Detroit 7.

This new press, known as the Series 55, is capable of producing as many as 50 preforms per min., and is designed primarily for making round and odd shapes, plain or with cored holes, having up to 3-in. cell depth and 3½-in. dia. It provides for dies up to 6 in. in dia. and 3¼ in. in thickness.

The press is powered by a 7½-h.p. motor through a variable speed drive so that speeds can be high for small work or slow for work requiring greater die fill time. A lever located near the work table operates a new type multiple-disk clutch and also a brake which can stop the press at any part of the stroke. Power is transmitted to the crank shaft through a special cone worm drive which delivers extremely high loads yet requires a minimum of space.

Adjustments can also be made for pres-



Ability to make adjustments rapidly gives this press great operational flexibility.

sure, hardness, weight, thickness, and to compensate for variations in the length of the core rod. A positive action overload release prevents damage to the press when maximum pressure is exceeded.

Special attachments which can be supplied with the press include: direct pressure reading instrument; a combination hydraulic and air operated lower plunger mechanism to provide even greater pressure uniformity on both sides of the work; and a one-shot lubricating system.

MOORE JIG BORER built with MEEHANITE® CASTINGS for...

Fig. 2. Typical set-up of Meehanite extension parallels.

"Control of Hardness"

"Uniform Grain"

"High Strength"

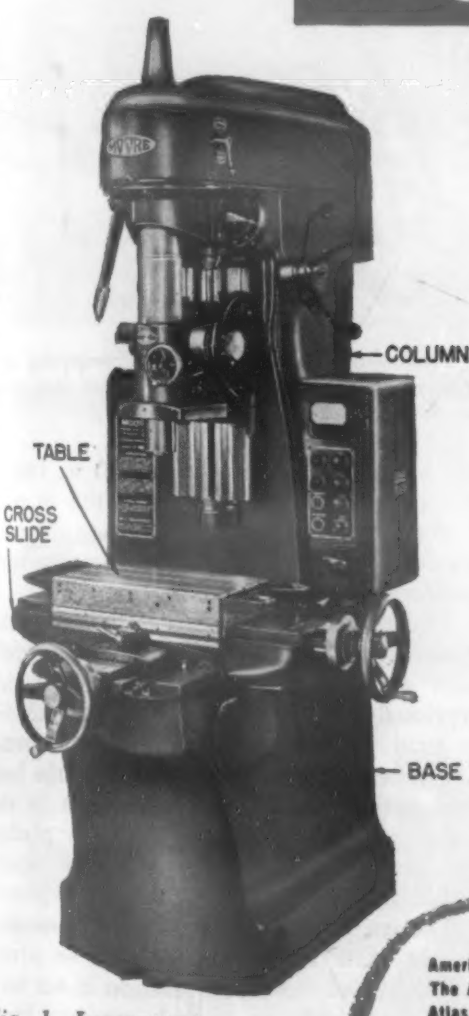


Fig. 1. Important Meehanite castings used in the construction of the Moore No. 2 Jig Borer.

The precision jig borer illustrated (Fig. 1), manufactured by the Moore Special Tool Co., Inc., Bridgeport, Connecticut, uses Meehanite castings extensively because of their contribution to the quality, accuracy and precision operation of this machine tool.

The important castings indicated are, according to the chief engineer of the company, specified as Meehanite castings for the following reasons:

1. "Close control of hardness for maximum wear resistance, yet just within the range of hand scraping."
2. "Uniform close grain for good machinability and absence of blow holes."
3. "High tensile strength and resistance to deflection."

In addition a number of fixtures similar to the extension parallels (Fig. 2) are Meehanite castings for similar reasons.

Complete machining data for various types of Meehanite castings is tabulated and illustrated in our new Bulletin No. 29 "How to Machine Meehanite Castings." For a copy write to any of the foundries listed.

MEEHANITE FOUNDRIES

American Brake Shoe Co.	Mahwah, New Jersey
The American Laundry Machinery Co.	Rochester, New York
Atlas Foundry Co.	Detroit, Michigan
Banner Iron Works	St. Louis, Missouri
Barnett Foundry & Machine Co.	Irvington, New Jersey
E. Long Ltd.	Orillia, Ontario
E. W. Bliss Co.	Hastings, Mich. and Toledo, O.
H. W. Butterworth & Sons Co.	Bethayres, Pennsylvania
Continental Gin Co.	Birmingham, Alabama
The Cooper-Bessemer Corp.	Mt. Vernon, Ohio and Grove City, Pa.
Crawford & Doherty Foundry Co.	Portland, Oregon
Farrel-Birmingham Co., Inc.	Ansonia, Connecticut
Florence Pipe Foundry & Machine Co.	Florence, New Jersey
Fulton Foundry & Machine Co., Inc.	Cleveland, Ohio
General Foundry & Manufacturing Co.	Flint, Michigan
Greenlee Foundry Co.	Chicago, Illinois
The Hamilton Foundry & Machine Co.	Hamilton, Ohio
The Henry Perkins Co.	Bridgewater, Massachusetts
Johnstone Foundries, Inc.	Grove City, Pennsylvania
Kanawha Manufacturing Co.	Charleston, West Virginia
Koehring Co.	Milwaukee, Wisconsin
Lincoln Foundry Corp.	Los Angeles, California
Otis-Fensom Elevator Co., Ltd.	Hamilton, Ontario
Pohlman Foundry Co., Inc.	Buffalo, New York
Rosedale Foundry & Machine Co.	Pittsburgh, Pennsylvania
Ross-Meehan Foundries	Chattanooga, Tennessee
Shenango-Penn Mold Co.	Dover, Ohio
Sonith Industries, Inc.	Indianapolis, Ind.
Standard Foundry Co.	Worcester, Massachusetts
The Stearns-Roger Manufacturing Co.	Denver, Colorado
Traylor Engineering & Mfg. Co.	Allentown, Pennsylvania
U. S. Challenge Co.	Centerville, Iowa and Batavia, Illinois
Valley Iron Works, Inc.	St. Paul, Minnesota
Vulcan Foundry Co.	Oakland, California
Warren Foundry & Pipe Corporation	Phillipsburg, New Jersey

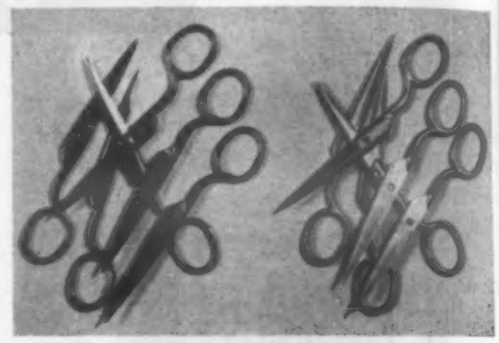
"This advertisement sponsored by foundries listed above."

Meehanite® NEW ROCHELLE, N. Y.

New Materials and Equipment

New Chemical Stripper for Nickel and Other Metal Coatings

Development of a stripper for chemically dissolving nickel and other metal coatings from steel without attacking the steel has been announced by *Enthone, Inc.*, 442 Elm St., Dept. MA, New Haven, Conn. The stripper is alkaline in nature, can be contained in a steel tank, and requires no electric current. The parts to be stripped are immersed in a solution of stripper salts, in



Nickel-plated parts before stripping are shown at left; at right, parts after stripping with Enthone's new compounds.

the temperature range from 160 to 180 F. Stripping speed varies from 0.002 to over 0.001 in. per hr., depending upon the concentration of salts and the operating temperature.

The process is stated to be good for the removing of nickel plate from bulk work, such as barrel nickel plated steel, which previously has been impossible or difficult to strip without attacking the base metal. The process does not etch or attack the base steel in any way. The steel is left in the same condition as it was prior to plating and, in most cases, the work needs merely to be dipped in acid and can be replated.

The stripper is also effective for removing copper plate from steel as well as silver, cadmium and zinc. The solution is not suitable for removing nickel coatings from zinc-base die castings or copper alloys.

● A method of coating each grain of a grinding wheel with a microscopically thin sheet of carbon in an isotropic vitrescent form has been announced by the *Mansco Grinding Wheel Co.*, 2164 East 36 St., Cleveland 15. This process, known as the Buxite process, suits wheels to grinding carbide tools and other super-hard alloys. Fast cutting is accomplished with light passes that generate little heat, thereby preventing checking and cracking of the tool.

New Materials and Equipment

Hard Surfacing Powder Has Wide Application

A hard surfacing powder, called Surfaceweld A, has been made available by the *Lincoln Electric Co.,* Cleveland 1. The powder, to be applied with a carbon electrode, is used for depositing a thin chromium carbide type of hard surface that is highly resistant to abrasive wear and corrosion. The powder forms a paste when mixed with water which adheres to flat and curved surfaces.

The operating characteristics of this powder give it a wide field of application. It can be used with an a.c. arc with a single carbon electrode. It may also be applied with a twin carbon arc or may be used with d.c. carbon electrode negative.

The powder is designed for the following surfacing applications where the use of hard surfacing electrodes is not always practical: (a) thin work, (b) thin deposits, (c) for use with small a.c. welders. The hardness of the deposit is approximately 54 to 61 Rockwell C for one layer and 57 to 63 for multiple layers. Hardness depends somewhat on the amount of admixture. The deposit develops full hardness in the as-deposited condition; maintains hardness and resists scaling at elevated temperatures. Corrosion resistance is comparable to that of stainless steel.

The advantages of the powder form of hard surfacing may be put to good use on such jobs as maintaining the cutting edge of mixing blades, drill bits, surfacing augurs, dipper teeth, bucket lips, forming dies, cement block formers, scraper blades, and cableway drums. It is also excellent for withstanding the abrasive action of the earth on tools such as hoes, shovels, garden tools; and farm implements such as disk plows, plow share points, bean knives and corn cutters.

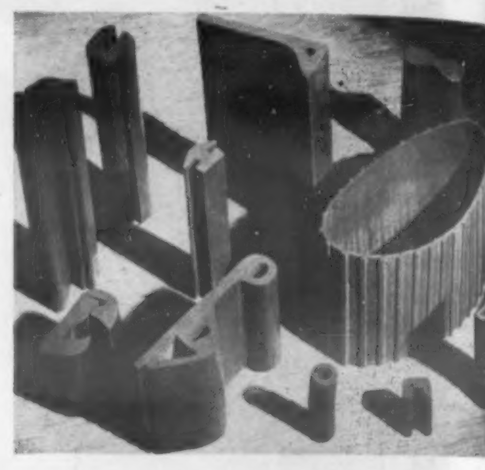
Synthetic Rubber Compound Fits Sub-Zero Applications

Development of a new Butaprene-based rubber compound has been announced by the *Stalwart Rubber Co.,* 165 Northfield Rd., Bedford, Ohio. This new synthetic is suitable for numerous applications in which rubber must withstand very low temperatures for prolonged periods of time and

New Materials and Equipment

still retain its flexible qualities. It is suggested for use in such products as refrigeration systems, aircraft, automotive and all other transportation equipment, outdoor lighting units, farm implements, and marine installations.

The new compound looks and acts like conventional rubber except for its ability



Some typical extruded shapes of the new low-temperature synthetic rubber.

to withstand the effects of temperatures as low as −50 F. It has a permanent set of 4%, a specific gravity of 1.25, and a durometer hardness of 55. Other features of the compound include the ability to resist mineral, animal and vegetable fats, and to remain unaffected by dilute acids, alkalies, petroleum products, hydrocarbons, and solvents; also to resist oxidation at high temperatures.

This rubber can be extruded into channels; lathe-cut or punched into gaskets, washers, and grommets; and molded into almost any practical shape. Special additives can adapt it for many applications (certain compounds will withstand extreme weathering, impact, and compression), and elongation can be "fixed" to meet individual specifications.

Latest Developments in Brazing and Soldering Fluxes

Three different companies recently announced newly developed flux compounds covering a variety of applications.

British Industries Corp., 315 Broadway, New York, has available an activated noncorrosive rosin flux in liquid form. The flux, known as Ersin Flux, is described as a high grade homogenously activated water white rosin that does not affect the noncorrosive

(Continued on page 120)

features of the original rosin. Soldered joints made with it are said not to corrode even after prolonged exposure to humidity. The flux reduces the surface tension of molten solder, causing it to wet metals rapidly, thereby increasing the speed of soldering.

Special Chemicals Corp., 30 Irving Place, New York 3, has announced a fluxing agent, Kwikflux No. 54, said to have improved wetting and penetration action, for all types of hard soldering, brazing and welding. It is suggested for use on the following metals: stainless steel, iron, steel, copper, brass, gold, platinum silver, Monel metal, nickel, nickel silver and other ferrous and nonferrous metals and alloys. It works with direct flame, gas, hydrogen, acetylene and muffle (direct and indirect) and induction heating.

Victor Equipment Co., 844 Folsom St., San Francisco 7, is marketing four new fluxes. They are No. 3 Flux for brazing brass and bronze, steel, clean cast and malleable iron; No. 5 Flux for moderate heat brazing of cast and malleable iron and can be used for "tinning" dirty castings; No. 7 Flux for high heat brazing of cast and malleable iron where base metal gets exceptionally hot; and No. 9 Flux for fast welding of cast iron. It will not cake when container is subjected to moderately high heat.

Fasteners Retain Re-Use Characteristics at 1200 F

With the introduction of a new nut for temperatures to 1200 F, the *Elastic Stop Nut Corp.*, 2330 Vauxhall Rd., Union, N. J., announces the availability of a specific nut design for fastener applications where temperature ranges from −65 to +1200 F. These fasteners are all self-locking, and provide permanent protection against vibration, impact and stress reversal in both fully seated and positioned settings.

The new Z-1200 series is specifically designed for service at 1200 F; they are said to retain their repeated re-use characteristics at this temperature. They are particularly suited for use in exhaust manifold systems, aviation gas turbine tail cones, and other installations where high temperatures create strength and seizure problems in ordinary fasteners. In the medium to high range, another group of nuts, the ZE series, will withstand sustained temperatures up to

New Materials and Equipment

550 F, without seizing the bolt or galling the threads.

Both ZE and Z-1200 series are available in hex and anchor styles. The ZE line comes in five thread sizes, ranging from 10/32

This high temperature nut is specifically designed to provide a self-locking nut that will be satisfactory at 1200 F.

to the fractional size of 3/8-24 in. National fine series with the 8/32, coarse, are also available in the hex nut. The Z-1200 series hex nuts come in four thread sizes, ranging from 10/32 to the fractional size of 3/8-24, while the anchor nuts of the Z-1200 series are available in three sizes: 10/32, 1/4-28, and 5/16-24.

Cutting Torch Attachment for Pipe Cutting Unit

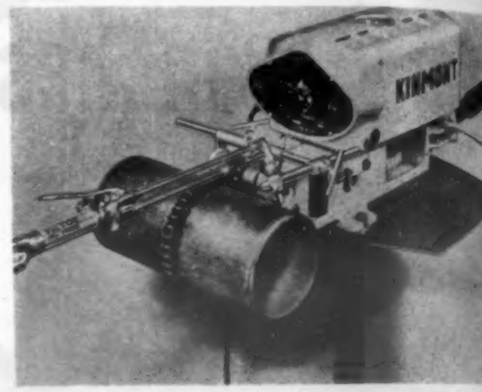
A cutting torch attachment is a new accessory now available for use with the power unit, manufactured by the *Kinmont Manufacturing Co., Inc.*, 716-718 W. Wilson Ave., Glendale, Calif. The principal features of this attachment are its provision for adjustment of the cutting torch in handling a wide range of pipe sizes, and its ability to maintain a smooth bevel and a square cutoff across the end of the pipe.

The adjustment range of the attachment permits its use on any pipe size from 3 in. up to 36 in. in dia. and on tanks up to 10 ft. in dia. when turned on a roller rack. The turning speed of the power unit is controllable while cutting operation is in progress. A foot switch controlling the turning operation leaves the operator's hands free to control the torch and speed adjustments.

An important feature of the power unit

New Materials and Equipment

is the patented split link chain drive which permits rapid fastening and unfastening of the work being turned. The drive chain holds the pipe tightly locked in position



A piece of pipe in position to be cut with torch attachment.

and turning against fixed rollers. This prevents creeping of the work and enables the attachment-held cutting torch to produce a smooth, accurately beveled and square pipe end.

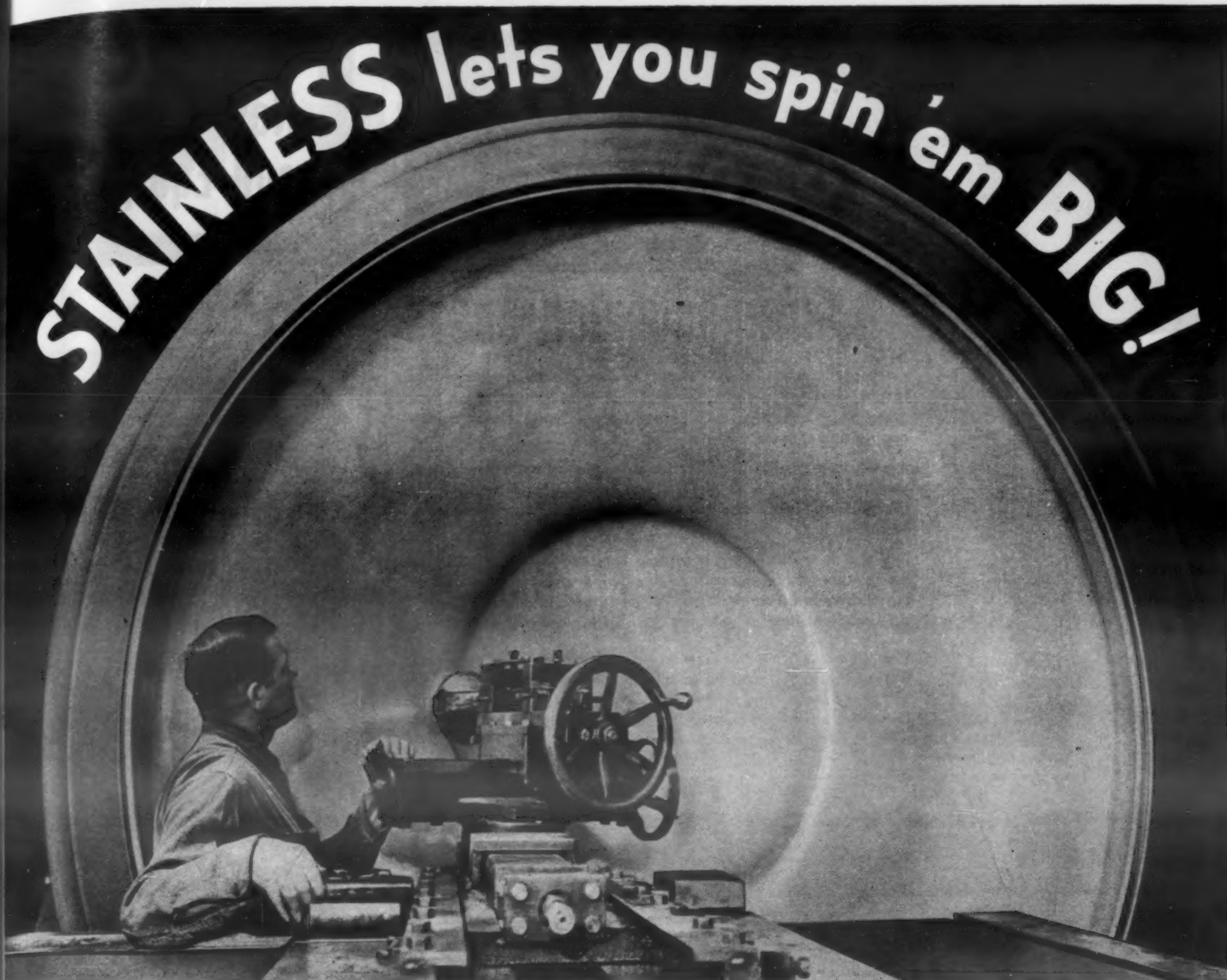
● A new portable Slitting Shear with slitting capacity of 1/8 in. in mild steel and 10 gage in stainless has been introduced by the *Beverly Shear Mfg. Co.*, Chicago. A unique adjustable shoe, which provides additional support at the toe of the upper blade holder, is said to give increased strength and cutting efficiency. A heavy frame is used to provide the necessary rigidity and strength to assure sharp, clean cutting and to prevent any side play or movement of the blades when making cuts in heavy gage steel.

Tube-Type High Frequency Unit Has Wide Range of Uses

Suitable for heating nonferrous as well as ferrous materials to any desired temperature is the new vacuum-tube high-frequency heating unit announced by *Lepel High Frequency Laboratories, Inc.*, 39 W. 60 St., New York. The machine can be used for hardening, soldering, brazing or melting.

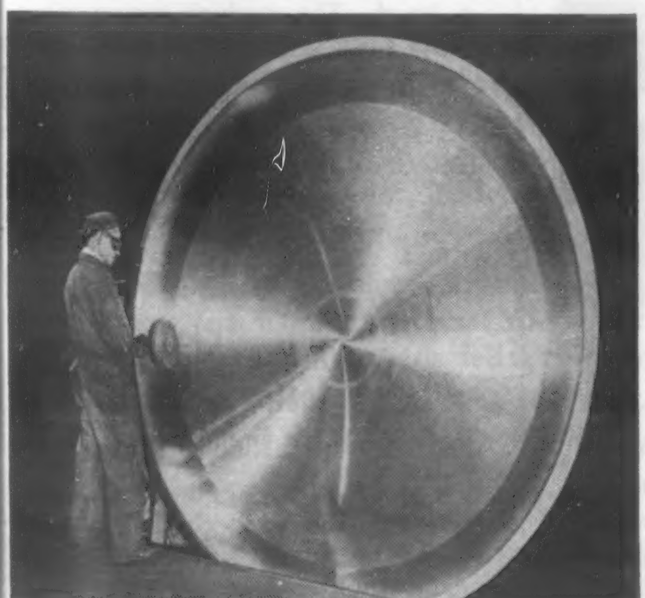
The unit is said to be the latest development in electronic tube-type high-frequency equipment and was developed as a companion machine to the recently announced spark-gap type heating unit for those who prefer to use the tube-type unit. The 20-kw. output of the tube machine, according

STAINLESS lets you spin 'em BIG!



This large stainless steel tank end being spun to the desired radius is made up of standard width sheets of "18-8" welded together and the welds ground smooth.

(Below) Another large stainless steel tank end, already spun to shape, shown here being polished.



HERE is austenitic chromium-nickel stainless steel, Type 305, being spun into a huge tank end. Another, of Type 302 . . . spun to shape and receiving a polish . . . is pictured at the left.

These large units attest to the adaptability of austenitic stainless steels to this method of fabrication.

Types 302, 304, and especially Type 305, lend themselves well to modern spinning operations according to the producers of these tank ends, Milwaukee Metal Spinning Company (Spincraft) of Milwaukee 8, Wisc. On a production basis, this company spins heads and ends for milk storage tanks ranging from 36 to 102 inches in diameter.

This is only one of many applications in which advantage may be taken of the various useful properties of chromium-nickel stainless steels.

You can trim bulk and deadweight by specifying correct types of stainless. They are strong yet tough, moreover, they resist wear and abrasion.

You get long service life because these alloys are resistant to attack by nearly all oxidizing acid conditions. They assure long, trouble-free performance of equipment, and hygienic cleanliness as well as economy in food, drug, chemical and other process industries.

Leading steel companies produce austenitic chromium-nickel stainless steels in all commercial forms. A list of sources of supply will be furnished on request.

EMBLEM OF INCO SERVICE
TRADE MARK

Over the years, International Nickel has accumulated a fund of useful information on the properties, treatment, fabrication and performance of engineering alloy steels, stainless steels, cast irons, brasses, bronzes, nickel silver, cupro-nickel and other alloys containing nickel. Write for "List A" of available publications.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

New Materials and Equipment

A vacuum-tube high-frequency heating unit suitable for ferrous and nonferrous metal heating.

to the manufacturer, is the same output as that of the spark-gap unit with 30-kw. input.

Housed in all-steel cabinet, the unit has heavy duty industrial type vacuum tubes, as well as grounded load coils, and permits use of flexible or rigid leads up to 8 ft in length. The machine consumes only 1 gal. of water per min. when idling, and less than 5 gal. at full load. The vacuum-tube unit is easily adjusted to any load, and requires no matching transformers or condensers.

New Coatings for Plastics Are Noncrazing

A group of coatings developed especially for use on Lucite, Plexiglas, Tenite II and polystyrene has been added to the line of product finishes manufactured by *United Chromium, Inc.*, 51 East 42 St., New York 17. Included in the group are both face and backing coats.

The A-147 series includes coatings that are available in clear, pigmented, and transparent colors. They are used either as a face or backing coat for Lucite and Plexiglas not under stress. The coatings have good resistance to moisture, perspiration and many chemicals.

Coatings in the A-149 series are available in transparent and pigmented colors, and

YOU SAVE up to 30%

YOU DON'T PAY FOR SCRAP LOSS OR "REJECTS" WHEN

Reynolds

MAKES ALUMINUM PARTS TO YOUR SPECIFICATIONS

NO SORTING OR SCRAP HANDLING

NO SHIPPING OR SUPPLY PROBLEMS

NO LABOR OR MACHINERY PROBLEMS

Scrap and rejects require handling and shipping that sacrifice profits. When you use Reynolds production facilities, this scrap and reject metal goes back into remelt at the source... you never bother with it, you pay no handling charge.

Here is a complete aluminum service from mine to finished products. You specify quantity and delivery. Reynolds delivers inspected parts or complete assemblies. You get all of the advantages of mass production without the worry of factory space, machine and manpower requirements. And you can count on a fixed cost. That's why Reynolds is delivering more and more parts and assemblies to some of the nation's largest manufacturers.

For the complete story of advantages, send for booklet explaining this unique service. Return the coupon below or call the Reynolds Sales Office listed under "Aluminum" in your classified telephone directory. Reynolds Metals Company, Industrial Parts Division, Louisville 1, Ky.

Reynolds Metals Company

INDUSTRIAL PARTS DIVISION

A complete aluminum fabrication service including blanking · embossing · stamping · drawing · spinning · forming · roll shaping · assembling and finishing ·

REYNOLDS METALS COMPANY
Industrial Parts Division
2051 South Ninth Street, Louisville 1, Kentucky

Send the new folder on Aluminum Parts and Assemblies.

Name________ Title________
Company________
Street Address________
City________ Zone____ State________

REYNOLDS PIONEERING MADE ALUMINUM COMPETITIVE...*TAKE ADVANTAGE OF IT!*

New Materials and Equipment

are used as decorative and protective co ings on Polystyrene, providing a good bo without crazing. One of the coatings in th series can be used as a wipe-in coati where indented designs are molded into th Polystyrene.

Coatings in the A-151 series, also avai able in transparent and pigmented colo are used as backing coatings only on Luci Plexiglas, and Tenite II where stress present. The coatings will not craze th plastic.

Sectional Flanging Press Also Use for Joggling and Upsetting

Designed for use in sectional flangi operations, this new hydraulic press pr duced by the *R. D. Wood Co.*, 402 Ches nut St., Philadelphia, is used also fo joggling and upsetting work. It delivers 200-ton capacity with the two vertical mai rams operated in unison. Its capacity wit a single vertical ram is 100 tons. Th horizontal ram, with a 72-ton capacity, has detachable crosshead of cast open-hear steel with bore and tapered key slot fo attachment of tooling. A pulpit arrangeme

This press has a 200-ton capacity.

conveniently locates the operating valves.

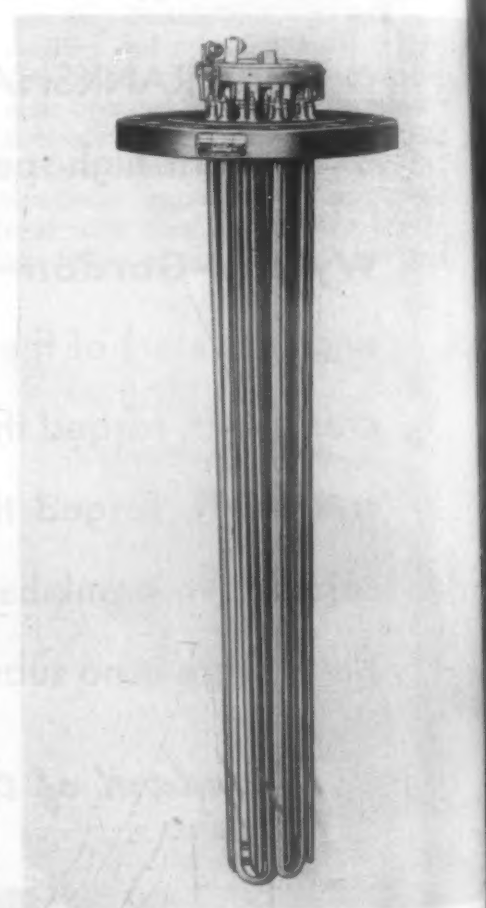
Arranged for accumulator operation and equipped for connection to accumulator pipe line, the press may also be furnished self-contained, with complete pumping units and control equipment. Designs for this hydraulic press are available from 150 to 300 tons, with larger sizes available for special requirements.

New Materials and Equipment

High-Temperature Immersion Heaters Allow Free Circulation

A new line of multiple-element elect[ric] immersion heaters for high-pressure, hig[h-] temperature applications has been a[n-] nounced by the *Edwin L. Wiegand C[o.]*, 7523 Thomas Blvd., Pittsburgh, Pa. C[a-] pacities of the new heaters, designated Ty[pe] TMO, vary from 1 to 100 kw., dependin[g] upon the job for which they are neede[d] and are obtained by arranging groups [of] tubular elements in mounting flanges.

The hair-pin shaped elements, of t[ri-] angular cross-section, are welded into th[e] forged-steel flanges and are so arrange[d] as to permit the liquid to circulate free[ly.] Units are available in steel, stainless steel [or]

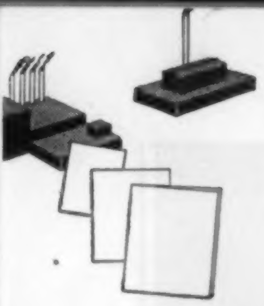


The number of elements in this imm[er-] sion heater can be varied to meet specif[ic] heating requirements.

Inconel sheaths as required for vario[us] corrosive liquids.

These immersion heaters are suggeste[d] for preheating air and other gases and fo[r] super-heating steam. With special gasket[s] and the special method by which the vario[us] units are welded to the forged steel flanges, the heaters will withstand high pressure[s] and resist leakage when used in heat transfe[r] liquids of high penetration.

(More News on page 138)



MANUFACTURERS' LITERATURE

Materials

IRON AND STEEL

Steel Analyses

This attractive, indexed chart contains easy-to-read tables giving complete analyses of high-speed and tool steels, stainless and heat resisting steels, carbon and alloy production steels, alloy steels, and nitriting, machinery and special purpose steels. Crucible Steel Co. of America. (1)

Color Code for Steel

The National Screw Machine Products Assn. has issued a new color code chart that represents the most practical combination of bar numbers and color types as used by the screw machine products industry, steel mills and warehouses. (2)

NONFERROUS METALS

Copper and Copper Alloy Specifications

A new, up-to-date, 28-page edition of the "Copper and Copper Alloy Specifications Index," No. B-34, published by the American Brass Co., is divided into two sections—Section I lists Anaconda's most generally used alloys, together with all applicable specifications; Section II lists specifications in numerical order with a brief description of materials covered as to grade, type, temper, anneal, etc. (3)

Aluminum Specifications Handbook

The Federated Metals Div. of the American Smelting & Refining Co. has issued a handy, 24-page guide of the latest specifications of ASTM, ASM, SAE, Federal, Army, Navy and others as they pertain to aluminum sand castings, permanent mold castings, die castings, wrought alloys and ingots. (4)

PARTS AND FORMS

Centrifugally Cast Aluminum Bronze Bars

New stock bars of Ampco Grade 18 centrifugal castings and the heat treated variations consisting of Ampco Grade 18-13, 18-22 and 18-23 are the subject of an attractive stock list card offered by Ampco Metal, Inc. Weights of the standard 12½-in. bars, and the chemicals and physicals of these bars are featured. (5)

Precision Investment Castings

An interesting article on precision investment castings is presented by the Arwood Precision Casting Corp. in this 16-page, illustrated bulletin, including a table of alloys found by Arwood to be most adaptable to its process. (6)

Precision Castings

The ability of the Precision Casting Div. of the Edmos Products Corp. for producing precision castings comparable with die castings in finish and dimensional accuracy, but of carbon, low alloy and stainless steels, brass, bronze and other high melting metals is discussed in this 4-page booklet. (7)

Color Code for Stainless Steel Tubing and Pipe

This 4-page, illustrated bulletin, No. 400, contains an attractive color code chart for the identification of Globe seamless stainless steel tubes and Gloweld electric welded stainless steel tubes. Globe Steel Tubes Co. (8)

Stainless Steel Moldings

A variety of standard Uni-Form stainless steel molding shapes, drawn to actual size with all pertinent dimensions, are featured in this 16-page, illustrated bulletin, No. 147, released by the Greene Manufacturing Co., Inc. (9)

Molded Plastic Trim

A wide variety of plastic, metal, and plastic and metal handles, pulls, gas cock handles, knobs, pendants, etc., are profusely illustrated and described in this 8-page bulletin available from the Grigoleit Co. Specifications are included. (10)

Bronze Bearings

A very large and complete line of bronze bearings, including several new sizes of general purpose and electric motor bearings, Universal bronze bars, and self-aligning bearings, is described and illustrated in this 84-page catalog, No. 490, offered by the Johnson Bronze Co. (11)

Sheet Metal Fabrication

The ability of the Lyon Metal Products, Inc., to manufacture steel or aluminum postwar parts, subassemblies and assemblies that can be fabricated in production runs is discussed, and a wide variety of made-to-order products manufactured by Lyon is illustrated in this 4-page bulletin, No. 651. (12)

Plastic Molding

The wide variety of industries served by the Mack Molding Co., Inc., specialists in molded plastic application, are featured in this 8-page, illustrated bulletin. (13)

Iron Castings

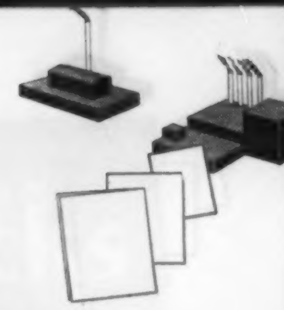
Complete data on Meehanite castings, noted for their ease in cutting and the smooth, even, highly polished finish which can be applied to them, as well as detailed instructions on how to machine these castings, are contained in this 20-page, illustrated bulletin, No. 29, offered by the Meehanite Metal Corp. (14)

Die and Wear Parts

Prices and specifications of Talide-tipped centerless grinder blades, sheet metal draw dies, wire and tube dies, drill jig bushings, gages, tubes, wear strips, etc., are included in this revised 36-page catalog, No. 48-WP, published by the Metal Carbides Corp. (15)

Stainless Steel Casting

The chemical composition, mechanical,



MANUFACTURERS' LITERATURE

ysical, heat and corrosion resisting prop-ies, heat treatment, machinability and ldability of Misco C-cast are listed in is 2-page bulletin, issued by the Alloy sting Div. of the Michigan Steel Cast-g Co. (16)

dustrial Wire Cloth

ll weaves, metals and sizes of wire cloth d fine wire for every type of applica-on, their specifications and prices are cluded in this attractive, 40-page, illus-ated catalog, No. B, offered by the Rey-olds Wire Co. (17)

ecision-Made Plastics

e Sillcocks-Miller Co. has issued an at-ctive, 12-page bulletin that describes and ustrates a wide range of precision-made astics products fabricated for commercial, chnical and industrial requirements. (18)

provement of Metals by Forging

omplete data on the proper techniques quired to forge successfully Monel metal d stainless steels and the development of ecialized techniques for the forging of gh temperature alloys are presented by e Steel Improvement & Forge Co. in an tractive, 44-page, illustrated catalog. (19)

PLASTICS

rface Treatment for Polystyrene

rface characteristics, processing data and pical applications of Logoquant, a new rface treatment for polystyrene, are fea-red in this 6-page, illustrated folder re-ased by the Bee Chemical Co. (20)

astics Molding Materials

etailed information on a complete line general purpose, heat resistant, impact, ectrical and specialty plastics molding aterials is presented in 50 data sheets ntained in a folder, No. CDC-12-1, issued the Chemical Dept. of the General ectric Co. (21)

NONMETALLICS

tadiene Rubber

he compounding process and fabrication Hycar American rubber, physical prop-ties of representative Hycar compounds, operties of Hycar vulcanizates, cements d Hycar-phenolic blends, a general im-ersion guide, etc., are all included in this 16-page, illustrated bulletin, available from the B. F. Goodrich Chemical Co. (22)

Industrial Friction Materials

A complete line of industrial friction materials individually engineered for every job is fully illustrated and described in this 4-page bulletin, No. 3736, released by the Thermoid Rubber Div. of the Thermoid Co. (23)

Methods and Equipment

HEAT TREATING

Pack-Hardening or Isolating Pastes

This 4-page, illustrated bulletin discusses Carburit, a new pack-hardening paste that hardens desired sections only, needs no special equipment, and penetrates the work rapidly, and Isopac, an easy-to-use isolating paste that keeps desired sections soft when hardening in box, salt bath or by other conventional methods. Denfis Chemical Laboratories, Inc. (24)

Standard Rated Industrial Furnaces

This 8-page, illustrated folder, No. SC-141, contains an up-to-date resumé of a complete line of standard rated furnaces for heat treating and a wide variety of other industrial purposes from metal melting to process air heating. Surface Combustion Corp. (25)

To obtain literature appearing on these pages, please refer to easy-to-use reply card on page 135.

WELDING AND JOINING

Welding Positioners

A profusely illustrated circular of Cullen-Friestedt Co. examines the factors involved in handling weldments of various sizes and shapes, and describes the use of positioners to provide economy, convenience and safety. (26)

Induction Heaters and Control Instruments

A variety of electric arc induction heaters and control instruments for preheating before welding and stress relieving after welding are described and illustrated in this 2-page bulletin offered by Electric Arc, Inc. (27)

Solder and Soldering Technique

A complete analysis of the properties and application of a variety of Flux Care soft solder alloys and soldering fluxes is presented by the Kester Solder Co. in a new, 28-page, illustrated manual. (28)

Hard Surfacing

Complete data on how to make the proper choice of surfacing materials when hard surfacing, and a variety of electrodes to use, their properties, procedure and typical applications, are presented by the Lincoln Electric Co. in this instructive, 16-page, illustrated bulletin, No. 466. (29)

Arc Welders

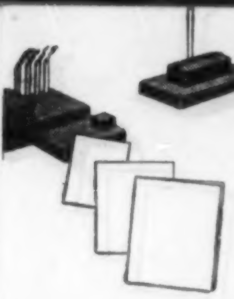
Detailed specifications and prices of a complete line of a.c. and d.c. M & T arc welders, produced by the Metal & Thermit Corp., are presented in convenient tabular form in this 4-page, illustrated bulletin. (30)

Standard Studs

This 4-page, illustrated price list contains dimensions and prices on a recently announced line of 60 standard M-G studs specially designed for end welding with the Nelson automatic stud welding gun. A partial list of special-purpose studs is also included in this bulletin, available from the Nelson Stud Welding Div., Morton-Gregory Corp. (31)

Soldering and Brazing

The ability of Soldering Specialties for producing soft solder and low temperature brazing alloys shaped to fit specific applications for mass production is discussed in this 4-page, illustrated bulletin. (32)



MANUFACTURERS' LITERATURE

Electrode Holders, Cable Connectors, Etc.

Specifications and prices of a complete line of electrode holders, cable connectors, ground clamps, machine terminals, cable splicers, etc., are featured in this 12-page, illustrated bulletin, No. 1948 T, available from the Tweco Products Co. (33)

FORGING AND FORMING

Mold Making with Low Temperature Melting Alloys

The Cerro de Pasco Copper Corp. has issued an informative, 8-page bulletin giving complete data on mold making with Cerro low temperature melting alloys. (34)

Tablet Presses

The Kux Machine Co. has issued an attractive, 32-page catalog that describes and illustrates various sizes and models of standard presses for automatically forming, at high production speeds, tablets and parts from dry, powdered or granulated materials. Specifications are included. (35)

Punch Presses

A variety of open back, inclinable standard punch presses, with 6- to 80-ton capacity are described and illustrated in this 8-page, pocket-size folder, No. L-8, offered by the L & J Press Corp. (36)

Bending Machines

A variety of hydraulic bending machines for swiftly producing widely diversified bends in all shapes and sizes of materials are described and illustrated in this 18-page catalog, available from the Pines Engineering Co., Inc. A helpful capacity chart is included. (37)

Hard Facing Forming and Drawing Dies

Complete data on the hard facing of forming and drawing dies are presented by the Wall Colmonoy Corp. in this 4-page bulletin. Three Colmonoy alloys for different size dies are suggested. (38)

Hole Punching Units

Type BL hole punching units for punching mild steel up to 1/8-in. thick, including the new punch retainer in the 1 3/8-, 2- and 2 1/2-in. units, are attractively displayed in this 32-page catalog, No. BL, distributed by the Wales-Strippit Corp. Specifications are included. (39)

MACHINING

Drills

This 128-page, illustrated catalog, No. 48, contains complete data on a wide variety of "ground-from-the-solid" drills, including information on cutting fluids, crankshaft pointing, pointing the drill, and tables of tap drill sizes, cutting speeds and consecutive listing of regular drill sizes. Specifications and prices are also given by the Ace Drill Corp. in this easy-to-use catalog. (40)

Abrasive Cut-Off Wheels

A variety of rubber bonded abrasive cut-off wheels for cutting unannealed steel, hard copper tubing, aluminum shapes, plastics, tungsten, etc., are illustrated and described in this 4-page bulletin, No. 4948 R, available from the Allison Co. Specifications are included. (41)

Milling Machines

This 36-page catalog, No. M-1662, describes and illustrates in great detail two models of milling machines, Nos. 2ML and 2MI, in plain, universal and vertical types, produced by Cincinnati Milling & Grinding Machines, Inc. Complete specifications and dimensions are included. (42)

Saw Bands

The facilities of the DoAll Co. for producing saw bands, and the many industries in which the blades are used, are profusely illustrated and described in this 4-page bulletin, No. 48-802. (43)

Broaching Machine

Detailed specifications of a double ram variable speed hydraulic surface broaching machine that incorporates both a new heavy duty double tip-down fixture and the new low pressure hydraulic system are featured in this 6-page, illustrated folder, No. DRV, available from the Lapointe Machine Tool Co. (44)

Machining Iron Castings

This 20-page, illustrated bulletin, No. 29, presents in great detail an accumulation of machining data on how to machine Meehanite castings, divided according to the type of machine tool on which the operation is performed. Very useful as a set-up guide, this bulletin is available from the Meehanite Metal Corp. (45)

Automatic Chucking Machine

Exclusive features and specifications of the Model 23A multiple spindle, tool rotating automatic chucking machine are presented in this 4-page, illustrated bulletin, issued by the New Britain-Gridley Machine Div., New Britain Machine Co. (46)

Bench Belt Grinders

Both the Type BBS bench belt grinder and Type DBS double belt bench grinder are fully described and illustrated in this 4-page bulletin, No. 664, issued by the Porter-Cable Machine Co. A list of standard equipment and specifications is included. (47)

Drilling Machines

The improved features of the Models D-2... and D-28 drilling machines produced by the Sibley Machine & Foundry Corp. are listed in this illustrated bulletin, No. 6... (48)

Hydraulic Duplicators

The extent to which exact duplication can be accomplished by installing hydraulic duplicators with 1-, 2- or 3-dimension on all sizes of boring mills, milling machines, lathes, planers, grinders, etc., is discussed in this 4-page, illustrated bulletin, available from the Walker Hydraulic Duplicator Co. (49)

CLEANING AND FINISHING

Protective Coating

The American Chemical Paint Co. has issued a 6-page, illustrated folder, No. 70..., covering "Cold Spray Granodizing," a protective zinc phosphate coating process for steel. Typical applications are included. (50)

Precision Electronic Photometer

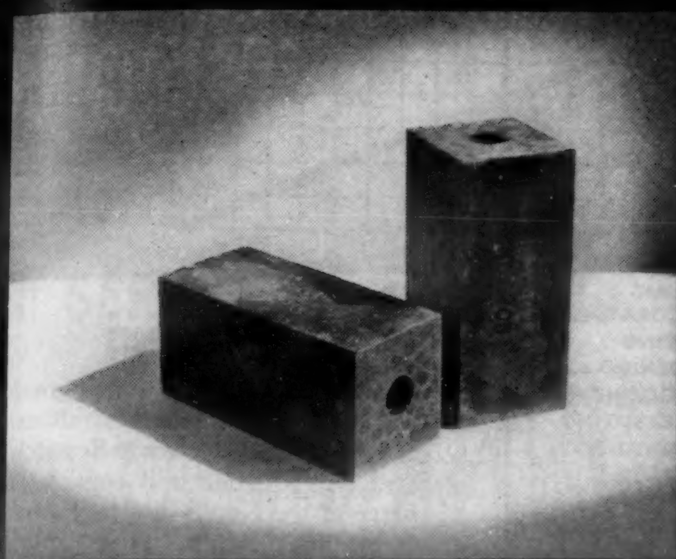
The many attractive features and numerous applications of the Color Densitometer, a precision electronic photometer of the direct reading type, are listed by Ansco in its 4-page, illustrated bulletin, No. F 19-8... (51)

Paint and Air Heater

Precision control of all essential temperatures for ideal spray finishing under heat through the use of the Dualheet paint and

CRYSTOLON Slag Hole Blocks

Pay Their Way in the Foundry



CRYSTOLON slag hole blocks, made by Norton Company of densely bonded silicon carbide grain, give long trouble-free service in foundry cupolas. The hard, dense surface of these chemically inert blocks is resistant both to the abrasion and penetration of molten slag. CRYSTOLON blocks resist all slag action either by corrosion or erosion. Consequently the hole size is maintained for a longer period of time giving better control of the flow. These rugged slag hole blocks are highly refractory and will neither soften nor spall at temperatures up to 1650°C.

NORTON REFRACTORIES LIKE HEAT

NORTON COMPANY · WORCESTER 6, MASS.

News of...

ENGINEERS COMPANIES SOCIETIES

Engineers

Dr. *Kenneth H. Kingdon*, atomic energy pioneer, has been appointed assistant director of the General Electric Research Laboratory. Dr. Kingdon will continue to be in charge of the Knolls Atomic Power Laboratory, which G.E. is operating for the Atomic Energy Commission.

The newly created position of executive technical engineer for Federated Metals, division of the American Smelting & Refining Co., was accepted by *H. L. Smith*, an active field metallurgist for the past ten years. Mr. Smith's headquarters will remain at 615 Gross St., Pittsburgh.

Sylvania Electric Products, Inc. has appointed Dr. *J. R. Dedrick* section head of the advanced development group at its Metallurgical Research Laboratories. Dr. Dedrick was formerly associated professor of powder metallurgy at the University of California. Another addition to the staff is Dr. *B. H. Alexander*, previously professor of metallurgy at the Carnegie Institute of Technology.

Dr. *A. Paul Thompson* was named director of research of the Eagle-Picher Co., a post left vacant by the death of *Earle W. McMullen*. Dr. Thompson, who held a Senior Fellowship at the Mellon Institute of Industrial Research since 1932, will direct the research activities from the company's main research laboratory at Joplin, Mo.

Two key executives were recently named by the Westinghouse Electric Corp. to guide the research and engineering of its new Atomic Power Div. Dr. *William E. Shoupp*, who previously served as manager of electronics and nuclear physics research at the Westinghouse Research Laboratories, was appointed director of research of the division. *Robert A. Bowman*, formerly manager of condenser engineering at the company's Steam Div., accepted the position of manager of engineering.

The recent election of *Louis C. Edgar, Jr.* as president of the E. W. Bliss Co. has just been announced. Mr. Edgar previously had served as president of the H. & B. American Machine Co.

The American Steel & Wire Co. has made several changes in the operating personnel of its Spring Mill & Rail Bond Div. *Raymond E. Tibbetts* was named division superintendent, succeeding *Harry F. Clarke*, who has resigned. Mr. Tibbetts previously was

News of...

ENGINEERS COMPANIES SOCIETIES

customer contact representative for the division. *Harold J. Elmendorf* was promoted from division metallurgist to the position of chief spring engineer. And *Erick R. Karlson,* formerly planning engineer, has been made division supervisor—production planning.

W. J. Haring has accepted the position of technical director of the Quaker Chemical Products Corp. He previously was director of metals research for the company.

The election of *John S. Fisher* as president and director of the General Metals Powder Co. has been announced.

Three new associate directors of research in the Plaskon Div. of the Libbey-Owens-Ford Glass Co. include Dr. *J. A. Murray,* Dr. *J. Kenson Simons* and *David E. Cordier.*

The Westinghouse Electric Corp. has announced the resignation of *C. J. Burnside* after 24 years of service. Mr. Burnside has organized an independent industrial consultant service, with headquarters in Baltimore, but he will continue his association with Westinghouse as a consultant.

C. A. Scharschu has been appointed assistant technical director of the Allegheny Ludlum Steel Corp. Dr. *L. C. Hicks,* formerly associate director of research, succeeds Mr. Scharschu as director of research.

Four new vice presidents have been named by the Federal-Mogul Corp. They include *M. A. Hunter,* in charge of manufacturing; *Ernest R. Darby,* in charge of research; *Rogers S. Marquis,* in charge of industrial relations; and *Neil A. Moore,* in charge of the Service Div. All four will make their headquarters in Detroit.

The new manager of General Electric Co.'s laminated plastics plant at Coshocton, Ohio is *Alden K. McCollum,* formerly head of G.E.'s Kokomo motor plant. Mr. McCollum succeeds *Arthur C. Treece,* who was appointed assistant to the Plastics Div. manager last year.

The United States Steel Corp. has announced the appointment of *M. W. Reed,* formerly chief engineer, as vice-president—engineering. Mr. Reed succeeds *B. H. Lawrence,* who is retiring after over 44 years of service with United States Steel.

Leyshon W. Townsend has resigned as manager of the Composite Steel Div. of the Jessop Steel Co. to accept the position of assistant to the president of the American Cladmetals Co. Mr. Townsend will continue as director of Composite Steels, Inc., doing consultant work with this firm.

The appointment of *Melville Morris* as executive vice president and member of the Board of Directors of the Optimus Equipment Co. occurred recently.

The retirement of *Robert W. Moffett* as

News of...

ENGINEERS COMPANIES SOCIETIES

general manager of fabrication of the Lukens Steel Co. took effect Feb. 1. Two other changes at Lukens include the appointment of *Raymond M. Dennis* as manager of fabrication, By-Products Div., and *Frank C. Kardevan* as manager of fabrication, Lukenweld Div.

The newly created position of vice president and general manager of the Indiana Steel Products Co. has been accepted by *Robert F. Smith,* formerly vice president and sales manager of the company. *Frank A. Hayden* succeeds Mr. Smith as sales manager and was elected a vice president.

Stewart Kerr, a Detroit attorney, has been appointed executive secretary of the National Association of Engineering Companies.

Several changes among the officers of the International Nickel Co. of Canada, Ltd., resulted in Dr. *John F. Thompson* becoming president of the company. Dr. Thompson, formerly executive vice president, succeeds *Robert C. Stanley,* who will continue as chairman of the board. Dr. *Paul D. Merica,* vice president, now retains the title of executive vice president. And *Henry S. Wingate,* secretary, has become a vice president and will continue as secretary.

The Allis-Chalmers Manufacturing Co. has named *Frank H. Stohr* as general manager of its Norwood Works. Mr. Stohr, formerly executive vice president and a director of the Elliott Co., succeeds *R. W. Davis,* who will continue in an advisory capacity to the general manager.

Edward J. Hrdlicka, previously chief engineer, has been elected vice president in charge of engineering of the Hydraulic Equipment Co. He succeeds *Harold J. Zimmerman,* who resigned to re-enter the field of industrial engineering as an independent operator.

The Hydraulic Press Manufacturing Co. has announced the appointment of *John M. Dolan* as vice president in charge of sales. Mr. Dolan formerly was associated with the LeRoi Co. as vice president also in charge of sales.

James P. Malmstrom has joined the Standard-Thompson Corp. and will establish an electronics and aircraft equipment division for the company. The division will be located at 930 So. Ludlow St., Dayton, Ohio. Mr. Malmstrom recently was associated with the Harris-Seybold Co. as project engineer and production supervisor.

The appointment of *Nelson C. Walker* as district manager of the Berwick, Pa. plant of the American Car & Foundry Co. has been announced. Mr. Walker assumes the position formerly held by *Justus W. Lehr,* who has been granted an extended leave of absence.

News of...

ENGINEERS
COMPANIES
SOCIETIES

Companies

The formation of *Carlso'n, Inc.*, designers, engineers, and manufacturers of special production machinery and particularly resistance welding equipment, has been announced. Located at Griswold St. Ext., P. O. Box 846, Warren, Ohio, the officers of the company include A. L. Carlson as president, L. R. O'Neill is vice president, and H. A. Stix is secretary and treasurer. All were formerly associated with the Federal Machine & Welder Co.

The *Foundry Equipment Co.*, Cleveland, has purchased the industrial oven business of the *Young Brothers Co.*, Detroit. Foundry Equipment will operate the Young Brothers Co. under that name, and will continue the sale, manufacture and installation of Young Brothers ovens.

The construction of a new plant for the production of trichlorethylene, a chlorinated solvent widely used in industry chiefly as a degreasing and metal cleansing agent, has been announced by the *Niagara Alkali Co.* Located at Niagara Falls, N. Y., the plant is expected to be in operation early this year.

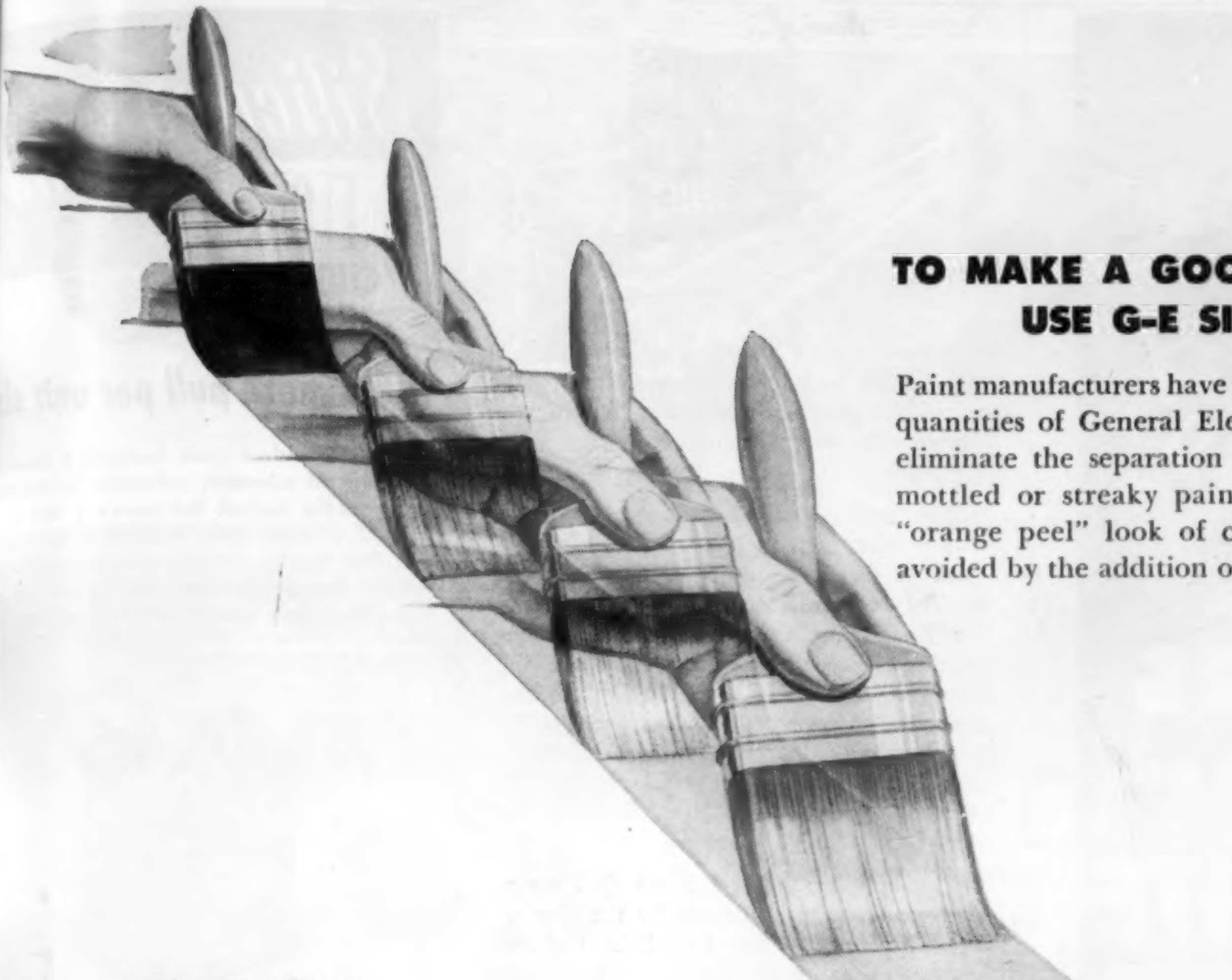
The first unit of the new $3,000,000 general chemicals manufacturing plant of the *B. F. Goodrich Chemical Co.* at Avon Lake, Ohio, is scheduled to start operations in the second quarter of this year. New plasticizers for vinyl and synthetic resins will be the first products made in the new plant.

Negotiations to combine the *Taylor-Wharton Iron & Steel Co.*, New York City, and the *Weir Kilby Corp.*, which involved an exchange of stock, have been completed. There will be no change in the management or corporate names of either of the companies.

The *Central Iron & Steel Co.*, Harrisburg, Pa., a subsidiary of the *Barium Steel Corp.*, has spent approximately $2,000,000 during the past year in enlargements and improvements to its steel making and plate rolling facilities. This expansion will substantially increase Central's ingot capacity and double its plate finishing capacity.

The formation of the *Michigan Oven Co.*, who will design, fabricate and distribute industrial ovens of all types for operating temperatures to 1100 F, has been announced. Located at 4544 Grand River Ave., Detroit 8, the company officers include R. J. Ruff, president; E. C. Herrington, vice president; and P. A. Meyer, secretary. All three were former employees of the Young Brothers Co.

The *Kenmore Metals Corp.* has increased its plant capacity approximately four times through the acquisition of a long term lease on part of the property formerly occupied



TO MAKE A GOOD PAINT BETTER USE G-E SILICONE OIL

Paint manufacturers have found that by adding small quantities of General Electric silicone oil they can eliminate the separation of pigments which causes mottled or streaky paint surfaces. Similarly, the "orange peel" look of certain lacquers has been avoided by the addition of G-E silicone oil.

How G-E Silicones can help you

ould your manufacturing efficiency be increased by using emically inert materials that maintain thermal stability extreme temperatures? Then you'll want to explore the ssibilities of General Electric silicone products.

G-E SILICONE RUBBER. This material will not soften at 0 F, or become brittle at –70 F. It is available in extruded apes, in compression-molded sheets, in paste form, or in ilormade compounds to meet specific requirements.

G-E SILICONE OILS. Their relatively stable viscosity at tem-eratures as high as 400 F, or as low as –90 F, recommend ese oils for dielectric or hydraulic liquids, for cooling or eating baths, and as mold release agents.

G-E SILICONE EMULSIONS. As mold release agents, these ater-diluted emulsions help to assure smooth castings and uick release—reduce the break-in time of new molds.

G-E SILICONE GREASES. Because of their resistance to hemicals and heat, these are excellent lubricants for plug ocks and valves. They also provide the heavier-bodied re-ease agents needed in the tire and mechanical rubber goods industries.

ANT TO KNOW MORE ABOUT G-E SILICONES? Write us about *your* production prob-ems. Let us help you solve them with one or more of these remarkable materials. ection 36-3, Chemical Department, General Electric Company, Pittsfield, Mass.

You can put your confidence in

GENERAL ELECTRIC

CD49-Q3

News of...

ENGINEERS
COMPANIES
SOCIETIES

by the American Brake Shoe Foundry at 380 Ninth St., Jersey City, N. J. The company's present production facilities at Warren, Pa. will be moved to the Jersey City plant.

The *Linde Air Products Co.*, unit of the *Union Carbide & Carbon Corp.*, New York 17, has announced its entry into the field of organosilicon chemicals. It is currently offering four organosilicon compounds of the alkyltrichlorosilane and the alkyltriethoxysilane type in pilot-plant quantities. However, as production facilities expand, greater quantities of these silane chemicals will be available, as well as other organosilicons in addition to the ones now offered.

The appointment of *Ebret & Kinsey*, Chicago, as sales engineers by the *American Flexible Coupling Co.*, Erie, Pa., has just been announced.

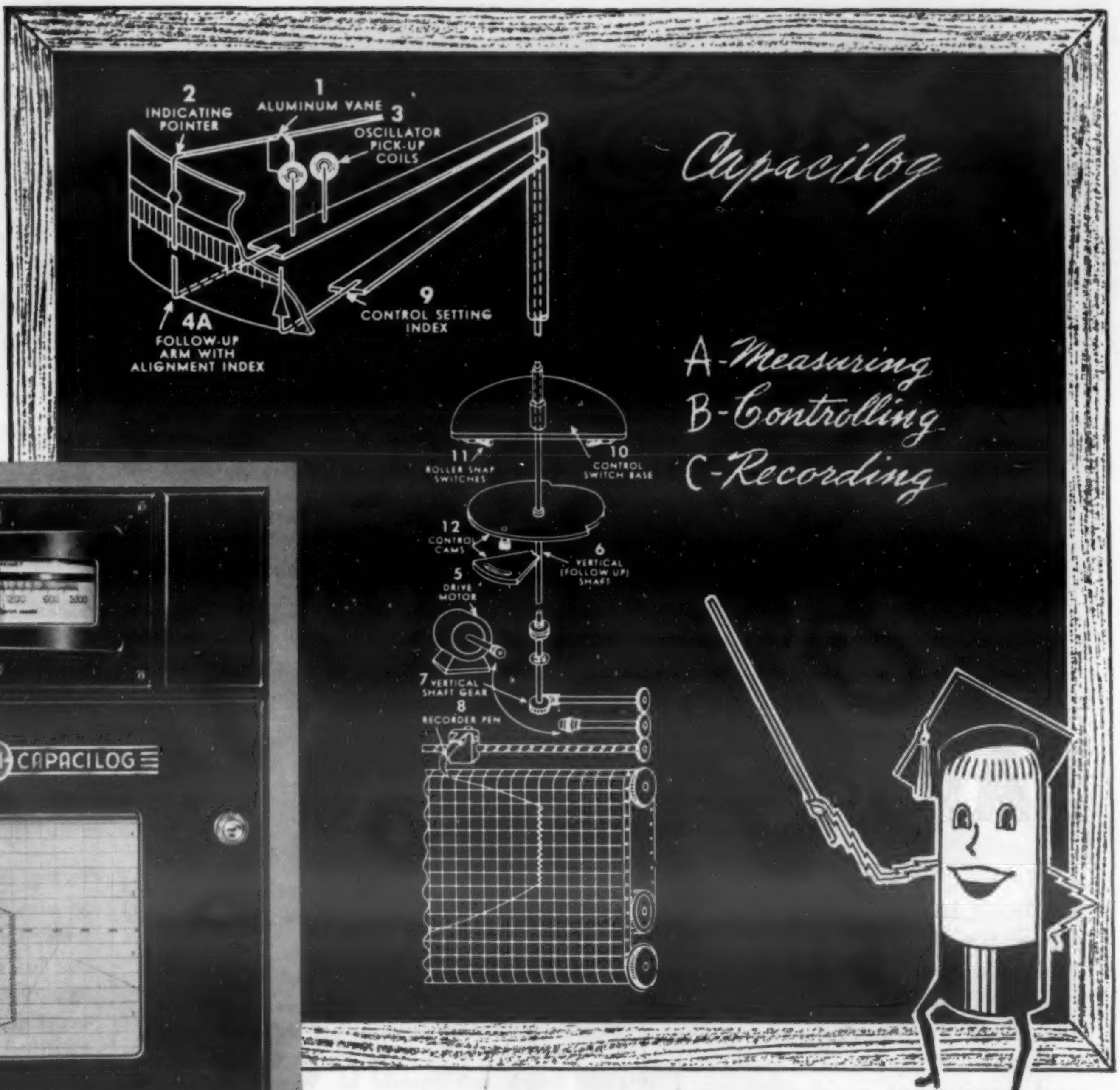
Societies

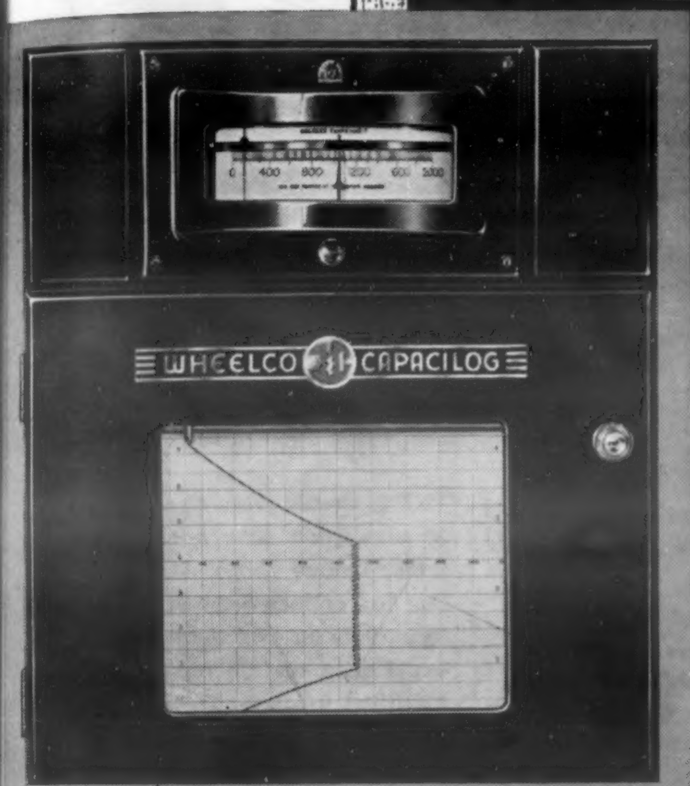
A two-day symposium on non-destructive testing of materials will be held in conjunction with the dedication of the White Oak *Naval Ordnance Laboratory* at Silver Spring, Md., Mar. 24-25. Authorities in the field of materials testing from both industry and the Services will present papers on recent progress of X-rays and other non-destructive tests.

The *Society of Plastics Engineers* elected national officers for 1949 at its recent annual meeting. They include: president—Mario Petretti, general manager of the Plastics Div., Noma Electric Corp.; vice president—William J. Dunnican, Borden Co. Chemical Dept.; secretary—M. Scott Moulton, B. F. Goodrich Chemical Co.; and treasurer—E. Todd Clark, Burkhart Manufacturing Co. Prize winners in the Prize Paper Contest of the Society were announced at the same meeting. They were A. R. Morse, Reed-Prentice Corp., recipient of the first prize; Ronald D. Beck, Continental Can Co., second prize; and Irving Silver, Naval Ordnance Laboratories, and Warren J. Prince, a consulting engineer, divided the third prize.

The fifteenth annual Engineers' Day of the *Colorado School of Mines* will take place Apr. 22-23, at Golden, Colo. The event will feature technical sessions in mining, metallurgy, petroleum production and refining, geophysics and geology, as well as exhibits.

The new president of the *Society of Automotive Engineers* is Stanwood W. Sparrow, vice president in charge of engineering of the Studebaker Corp.; B. B. Bachman, vice





Processing Industries are *sold* on the CAPACILOG . . . . because:

. . . Engineers like the Electronic System *simplicity* of the Capacilog Recorder as demonstrated on the "blackboard" chart. It uses the same Wheelco "Electronic—No Contact—Principle" that made pyrometer controller history a decade ago.

An aluminum vane (1) mounted on the indicating pointer (2) of the temperature measuring system is free to pass without physical contact between the oscillator coils (3) mounted on the follow-up arm (4A) and is coupled to the scriber mechanism which is operated by drive motor (5) through vertical shaft (6) and gear-drive (7).

An almost imperceptible movement (.004 to .006) of the vane between the coils effects a change in current that causes the pen drive motor to operate for accurate recording and exceptionally close control.

Whether your application is in the Metal, Chemical, Ceramic, Plastic or Laboratory Classification, there is a model for your purpose.

WHEELCO INSTRUMENTS COMPANY
861 W. HARRISON ST., CHICAGO 7, ILL.

Please send me the Bulletin(s) checked below:

☐ C2—Strip Chart Recorder
☐ Z6500—Condensed Catalog

Name.................................... Title..................
Company..
Street...
City.................................... State..................

WHEELCO *Electronic* CONTROLS

RECORDERS • COMBUSTION SAFEGUARDS • CONTROLLERS

News of...

ENGINEERS
COMPANIES
SOCIETIES

president of the Autocar Co., was re-elected treasurer of the Society.

Receipt of a Postgraduate Fellowship in Metallurgy, believed to be only the second scholarship in that field ever given by the E. I. du Pont de Nemours & Co. to an American college or university, was announced by the *Carnegie Institute of Technology.* The fellowship will not be awarded until April or May.

The *American Weldment Manufacturers Assn.,* 332 So. Michigan Ave., Chicago 4, is now prepared to accept representative members of the weldment industry throughout the United States and Canada into its membership. William C. Simpson, manager of sales for Lukenwald, Div. of the Lukens Steel Co., is president of the Association; Hugh Hodges, manager of the Weldment Div., Graver Tank & Mfg. Co., is secretary; and A. A. Fredrickson, vice president of the Lakeside Bridge & Steel Co., is treasurer.

R. S. Reynolds, Jr., Reynolds Metals Co., was elected president of the *Aluminum Association* for the ensuing year. Re-elected to their former offices were A. V. Davis, Aluminum Co. of America, as chairman of the board, and Donald M. White as secretary and treasurer.

Dr. Edwin Ward Tillotson, assistant director of the Mellon Institute, has been selected as the recipient of the Bleiniger Memorial Award of 1949, presented by the *American Ceramic Society* for distinguished achievement in the field of ceramics.

The *Resistance Welder Manufacturers' Assn.* elected B. L. Wise as president for the current year. Mr. Wise, director of production of the National Electric Welding Machines Co., succeeds T. S. Long, elected chairman of the Executive Committee. The new vice president of the Association is T. Embury Jones, president of the Precision Welder & Machine Co. Re-elected to their former offices were George A. Fernley as executive secretary and H. R. Rinehart as secretary-treasurer.

The *E. I. du Pont de Nemours & Co., Inc.,* Wilmington, Del., has instituted a program of grants-in-aid to ten universities for the 1949-50 academic year for unrestricted use in the field of fundamental chemical research. The program will be on a trial basis, but should it turn out satisfactorily, it will be continued for a period of five years. The ten universities offered the grants-in-aid of $10,000 each are: California Institute of Technology, Cornell University, Harvard University, Massachusetts Institute of Technology, Ohio State University, Princeton University, Yale University, University of Illinois, University of Minnesota, and University of Wisconsin.

WHAT USED TO HAPPEN TO SNOW SHOVELS IN SUMMER?

It wasn't good.
But it doesn't happen
with aluminum shovels.
Because ALUMINUM LASTS.

You probably weren't thinking of years of service. You bought your aluminum snow shovel because it was so light, so easy to handle. Nature made aluminum light. But a lot of other things had to happen to make aluminum that would *last.*

Alcoa made those things happen.

A snow shovel needs strength, as well as corrosion resistance. It cost millions to find the right alloys of aluminum for that. Alloys strong as steel, that could be rolled into sheet, for blades; drawn into tubes, for handles; made into rivets, to join them.

Sounds like a lot of work to make a better snow shovel. Hundreds of Alcoa research people working thousands of hours on alloys . . . hundreds of others spending years on fatigue tests, tensile tests, corrosion tests. But it enables us to say . . . "Alcoa Aluminum lasts!". . . and mean it.

That means more than just better snow shovels. It means better automobile parts. Better stepladders. Garage doors. Awnings. Screens and storm windows. All the things that didn't use to last, unless you painted them well and often.

That makes things of Alcoa Aluminum worth looking for. Worth buying. ALUMINUM COMPANY OF AMERICA, 660 Gulf Building, Pittsburgh 19, Pa.

ALCOA — *first in Aluminum*

THE METAL THAT *Lasts*

BOOK REVIEWS

Residual Stress

EVALUATION OF RESIDUAL STRESS. *By K. Heindlhofer. Published by McGraw-Hill Book Co., Inc., New York, 1948. Fabrikoid, 5¾ x 8¼ in., 196 pages. Price $4.00.* This treatise on the nature, detection, measurement and analysis of residual stress describes the use of strain gages and interpretation of the results with accuracy. Limitations of stress analysis are also discussed.

The chapters cover the following: the nature and significance of residual stress; limitation imposed upon stress analysis by the nature of the metal; displacement, strain, and stress; mapping of residual stresses; detection and measurement of residual stress; strain gages; examples of experimental stress analysis; interpretation of some of the results.

Other New Books

COMMON SENSE IN STEEL TREATING. *By W. R. Bennett. Published by W. R. Bennett, Brattleboro, Vt., 1948. Fabrikoid, 5¼ x 7½ in., 86 pages. Price $2.00.* Deals with specific problems in steel treating, points out dangerous steps, and advises methods to eliminate them entirely.

DESIGN FOR WELDING. *Published by James F. Lincoln Arc Welding Foundation, Cleveland 1, Ohio, 1948. Fabrikoid, 6 x 9 in., 1024 pages. Price $2.00 in U.S.A.; $2.50 elsewhere.* Abstracts of 82 award papers submitted in the Design-for-Progress Award Program.

MATHEMATICS AT WORK. *By Holbrook L. Horton. Published by Industrial Press, New York 13, 1949. Fabrikoid, 6¼ x 9¼ in., 728 pages. Price $8.00.* Practical applications of arithmetic, algebra, geometry, trigonometry, and logarithms, illustrated by mechanical problems taken from actual practice. Contains 145 pages of standard mathematical tables, including logarithmic and trigonometric.

GAS WELDING AND CUTTING. *By C. G. Bainbridge. Published by Louis Cassier Co., Ltd., London S.E. 1, England, 1948. Cloth, 5¾ x 8¾ in., 312 pages. Price 15/.* Explains underlying principles of the methods and techniques of gas welding.

NOTES ON SOLDERING. *By W. R. Lewis. Published by Tin Research Institute, Middlesex, England, 1948. Heavy paper, 6 x 9¼ in., 88 pages. Free. (Readers in U. S. A. are requested to apply to Dr. Bruce Gonser, Battelle Memorial Institute, 505 King Avenue, Columbus 1, Ohio.)* Reviews researches of recent years, and presents facts likely to be of value to solder-users in a variety of industries.

Whether you use wire cloth in the manufacture of original equipment, or in a processing operation, the manufacturing facilities and experience of two great woven wire producers are available to save you time and money in the fulfillment of your requirements.

With plants on both the East and West Coasts, The Wickwire Spencer Steel Division and The California Wire Cloth Corp. are pioneers in the territories they serve. As precision fabricators of a dozen different weaves of wire cloth, we can supply wire cloth for screening, filtering, grading, cleaning or processing. Wissco and Calwico Wire Cloth is made in all commonly used metals to give long service under chemical action, corrosion, abrasion, moisture or high temperature.

If you have questions regarding wire cloth, the services of our engineers are at your disposal. Just write to our nearest office.

WISSCO *Wire Cloth* **CALWICO**

East of the Rockies it's **WISSCO**
WICKWIRE SPENCER STEEL
STERLING ST., CLINTON, MASS.

CF&I

CALWICO On the Pacific Coast
THE CALIFORNIA WIRE CLOTH CORP.
1080—19TH AVE., OAKLAND, CAL.

The Last WORD

by **FRED P. PETERS,** *Editorial Director*

What Price Glorium?

I'm all confused:
My brainium
Was reeling from
Uranium
So famed in song
And storium
(Right to the point
of borium).
But oh! it cannot
Rainium
But what it has to
Porium
For first it poured
Uranium
And now it's reigning
Thorium!

Sometimes It *Is* the Material!

On occasion we've added our cackle to the spreading protest against blaming every operating or service trouble on the material. All too often it's the design or production practice that's at fault, and the materials engineer has enough crosses of his own to carry without doing triple duty for the notches or botches of his partners in crime.

As a matter of fact, it isn't the material we should be defending but rather the materials engineer, who is evidently the favorite target in many shops whether the charge be directed against his materials or his processing practice. Howard Boyer of American Bosch tells of a case known to him, where the materials engineer (in this case the company's chief metallurgist) almost took the rap for sins not of his doing. For several weeks this company had been making a complicated part—a shell—with internal threads, a flange and other gimmicks to bring furrows to the brows of all. All of a sudden rejections for size began to show up and soon the production losses due to oversize parts became prohibitive. The plant management decided that the heat treating operation, which was under the materials engineer's supervision, must be the culprit because in no other way could the pieces possibly grow oversize (and anyway it fitted the classic pattern of blaming things on the materials engineer). So the materials engineer dutifully collected several raw material blanks, and prepared to heat treat them individually with different processes, times and temperatures—first, however, recording their initial dimensions so that he could determine which treatment produced the least growth. And lo! and behold! at that point they discovered that the raw material was originally oversize more than enough to account for the so-called "growth." Mr. Boyer reports that thereafter there was high respect for their materials man in that plant, at least for a few days.

Nuts and Bolts

One of the questions in a recent high-school science course exam was: "Define a bolt and nut and explain the difference, if any." As proof that there is too a place for women in engineering, we give you verbatim the answer written by a girl in the class:

"A bolt is a thing like a stick of hard metal such as iron with a square knob on one end and a bunch of scratching wound around the other end. A nut is similar to a bolt only just the opposite, being a hole in a little chunk of iron sawed off short with wrinkles around the inside of the hole."

And every word of it is true!

March Memos

Leo Tarasov of Norton Co. is collecting a mountain of impressive data on the relationships among so-called grinding cracks, grinding practice, heat treating practice, the material being ground ("grindability," no less), and its endurance limit. He says it all shows that it's not true what they say about grinding; the question shouldn't be whether to grind but how to grind. . . .

Bill Reich and Paul Gorsuch of G.E. in Schenectady showed us recently a useful high-temperature strain gage the latter had developed and which a lot of other engineers could use in *their* business, too. They promised to air it in print, when it's "perfected." Maybe letters from some of you would be more influential than a mere editor's pleas. Why not try? . . . .

The case of Paul Merica, recently elevated to executive vice president of International Nickel, is cause not only for congratulations to him, but also for noting the increasing number of originally highly technical men who are being called into top management jobs —and all doing very nicely, thank you. . . .

In materials engineering, the traditional factor of safety may often be a factor of ignorance, and is more and more the bugaboo of efficient design of modern mobile products. *A factor of safety of five or ten may keep a bridge neatly suspended in air but it will seldom get a 4-motored airplane off the ground. . . .*

Too many of us are work-wise and health-foolish, according to J. J. Kanter of Crane Co., now fully recovered from a physical breakdown last year, caused by his own unrelenting pressure on himself. Good advice for you and you and you and you. . . .

A. M. Bounds of Superior Tube says nonferrous fishing rods are increasing in popularity. Beryllium-copper tubing was successfully used by some Waltonites during the worst phase of the steel shortage, despite certain fabricating problems and a low modulus. Currently 24S aluminum is finding friends in this field. Now when I was a boy. . . .